Final

Steps 3b and 4 of the Baseline Ecological Risk Assessment
SWMUs 1 and 2
Naval Activity Puerto Rico
RCRA/HSWA Permit No. PR21700027203
Ceiba, Puerto Rico

Prepared for

Department of the Navy
Atlantic Division
Naval Facilities Engineering Command

Norfolk, Virginia
Under the
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Prepared by

CH2M HILL
Federal Group, Inc.

Baker
Environmental, Inc.

CDM
Federal Programs Corp.

FINAL

STEPS 3b AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT SWMUs 1 and 2

NAVAL ACTIVITY PUERTO RICO
RCRA/HSWA PERMIT NO. PR2170027203
CEIBA, PUERTO RICO

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DEPARTMENT OF THE NAVY
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Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

CH2M Hill
Herndon, Virginia

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LIST OF ACRONYMS AND ABBREVIATIONS

AET	Apparent Effects Threshold
AOC	Area of Concern
As	Arsenic
ASTM	Amercian Society of Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	Area Use Factor
AVS	Acid Volatile Sulfide
Baker	Baker Environmental, Inc.
bgs	below ground surface
BRAC PMO SE	Base Realignment and Closure Program Management Office South East
BW	Body weight
CEPA	California Environmental Protection Agency
CFR	Code of Federal Regulations
Cd	Cadmium
CLP	Contract Laboratory Program
cm	centimeter
CMS	Corrective Measures Study
CNO	Chief of Naval Operations
CTO	Contract Task Order
Cu	Copper
DCQAP	Data Collection Quality Assurance Plan
DI_x	Dietary intake for chemical x
DMP	Data Management Plan
DQO	Data Quality Objective
EA	Environmental Assessment
ERA	Ecological Risk Assessment
ER-L	Effects Range-Low
ER-M	Effects Range-Median
FC_{xi}	Concentration of chemical x in food item i
FIR	Food Ingestion Rate
FSAP	Field Sampling and Analysis Plan
GIS	Geographical Information System
GPS	Global Positioning System
HASP	Health and Safety Plan
Hg	Mercury
HQ	Hazard Quotient
IAS	Initial Assessment Study
IDW	Investigative Derived Waste

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

kg	kilogram
km	kilometer
kg/day	kilogram per day
LEL	Lowest Effects Level
LL-PAHs	Low Level Polycyclic Aromatio Hydrocarbons
LOAEL	Lowest Observed Adverse Effects Level
m	meter
MeHg	Methlymercury
MeSe	Methylselenium
mg/kg	milligram per kilogram
mg/kg-BW/day	milligram per kilogram body weight per day
MHSPE	Ministry of Housing, Spatial Planning and Environment
MSD	Minimum Statistical Difference
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAPR	Naval Activity Puerto Rico
NEESA	Naval Energy and Environmental Support Activity
NFESC	Naval Facilities Engineering Command
NSRR	Naval Station Roosevelt Roads
NAVFAC ATLANTIC	Naval Facilities Engineering Command, Atlantic Division
NOAEL	No Observed Adverse Effects Level
OBIS	Ocean Biogeographic Information System
Pb	Lead
PDF_i	Proportion of diet composed of food item i
PDS	Proportion of diet composed of soil/sediment
PEC	Probable Effect Concentration
PEL	Probable Effect Level
PMP	Project Management Plan
PPE	Personal Protective Equipment
ppt	parts per thousand
PRDNR	Puerto Rico Department of Natural Resources
PRG	Preliminary Remediation Goal
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

Sb	Antimony
SC_x	Concentration of chemical x in soil/sediment
SCL	Standard Carapace Length
Se	Selenium
SEL	Severe Effect Level
SEM	Simultaneously Extracted Metals
Sn	Tin
SOP	Standard Operating Procedure
SSL	Soil Screening Level
SWMU	Solid Waste Management Unit
TEC	Threshold Effect Concentration
TEL	Threshold Effects Level
TOC	Total Organic Carbon
UCL	Upper Confidence Level
ug/kg	micrograms per kilogram
ug/g	micrograms per gram
USC	United States Code
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency
Zn	Zinc

1.0 INTRODUCTION

This document presents Step 3b (baseline risk assessment problem formulation) and Step 4 (baseline risk assessment study design/data quality objectives) of the Navy ecological risk assessment (ERA) process (Chief of Naval Operations [CNO], 1999) for Solid Waste Management Units (SWMUs) 1 (Army Cremator Disposal Site) and 2 (Langley Drive Disposal Site), located at Naval Activity Puerto Rico (NAPR), Ceiba, Puerto Rico. Steps 1 though 3a of the ERA process for SWMUs 1 and 2 have been finalized and are presented in the document entitled *Final Additional Data Collection Report and Screening Level Ecological Risk Assessment and Step 3a of the Baseline Ecological Risk Assessment at SWMUs 1 and 2* (Baker, 2006a). This report has been prepared under the Corrective Action provisions of the NAPR's Resource Conservation and Recovery Act (RCRA) Permit No. PR2170027203. This document is based upon previous investigations and has been prepared by Baker Environmental, Inc. (Baker) under contract to the Atlantic Division, Naval Facilities Engineering Command (NAVFAC Atlantic), Contract Number N62470-02-D-3052, Contract Task Order (CTO) 0108.

This Work Plan is to be used in conjunction with the Master Project Management Plan (PMP), Master Data Collection Quality Assurance Plan (DCQAP), Data Management Plan (DMP), and Master Health and Safety Plan (HASP) for NAPR, submitted under separate cover (Baker, 1995). Together, these plans provide all details regarding field investigation techniques, laboratory analysis, data validation, and data evaluation required to fulfill the requirements of the RCRA Facility Investigation (RFI) program. These plans provide the details for sampling and analysis protocols to be followed and general activities to be accomplished for the SWMUs 1 and 2 baseline ERA. Addendums to the DCQAP and HASP have been prepared to address specific issues related to this investigation (see Appendix A and Appendix B, respectively). This document will supplement the Master Plans with site-specific information for the SWMUs 1 and 2 baseline ERA.

1.1 Investigation Objectives

The primary purpose of the investigation at SWMUs 1 and 2 is to provide additional data with which to refine previous risk estimates for ecological receptors from potential exposures to chemicals identified as potential ecological risk drivers by the screening-level ERA (Steps 1 and 2) and Step 3a of the baseline ERA (see Table 1-1). Once the data outlined in this document are collected (Steps 5 and 6 of the ERA process), they will be evaluated, along with previously collected data, in order to develop refined ecological risk estimates (Step 7). If unacceptable risks are indicated following Step 7, these data also may be used to develop ecologically-based Preliminary Remediation Goals (PRGs) for sediment to aid the risk management decision-making process.

The components of the Step 4 studies, as outlined in this document, will provide multiple lines of evidence on which to evaluate potential ecological risks or existing ecological impacts. These lines of evidence are site-specific, direct measures of potential ecological effects and are thus preferable to the comparison of chemical concentrations in environmental media to conservative, non-site-specific screening values, and other overly conservative assumptions associated with food web exposures, which form the basis for screening-level risk estimates. The use of multiple lines of evidence also reduces the dependence on any one type of data and thus reduces the uncertainty of the analysis, allowing more confident decisions to be made about the need for, and extent of, remedial actions.

The specific objectives of the baseline ERA at SWMUs 1 and 2 are:

- Provide site-specific data (e.g., soil, estuarine wetland sediment, and open water [Ensenada Honda] sediment analytical data, bulk soil and estuarine wetland sediment toxicity test data, and tissue concentrations in terrestrial and aquatic food items with which to refine previous ecological risk estimates.

- Provide an examination of sea turtle life history information and a summary of available sea turtle habitat in the open water portions of SWMUs 1 and 2 to determine their potential for exposure to chemicals detected in Ensenada Honda sediment.

- Provide the necessary data with which to develop ecologically-based PRGs for soil, estuarine wetland sediment, and open water sediment to aid the risk-management decision-making process should unacceptable ecological risks be identified in Step 7 of the baseline ERA.

1.2 Report Organization

These project plans are organized as follows:

Section 1.0	Introduction
Section 2.0	Environmental Setting
Section 3.0	Baseline Risk Assessment Problem Formulation
Section 4.0	Study Design/Data Quality Objectives
Section 5.0	Field Sampling and Analysis Plan
Section 6.0	Project Schedule
Section 7.0	References

2.0 ENVIRONMENTAL SETTING

The sections that follow provide a brief description of the facility and SWMUs 1 and 2. The habitats occurring within and contiguous to each SWMU are also described, as well as the biota that may be present. The description of habitats and biota relies primarily on literature-based information for Puerto Rico and NAPR. This information is supplemented by observations recorded during a habitat characterization conducted within the vegetative units at and contiguous to SWMUs 1 and 2 from May 15 to May 19, 2000. The habitat characterization report, prepared by Geo-Marine, Inc. (Plano, Texas), is included as Appendix C.

2.1 Site History

NAPR occupies over 8,600 acres on the northern side of the east coast of Puerto Rico, along Vieques Passage with Vieques Island lying to the east about 10 miles off the harbor entrance (see Figure 2-1). NAPR was commissioned in 1943 as a Naval Operations Base, and was redesignated a Naval Station in 1957 (Naval Station Roosevelt Roads [NSRR]). In March 2003, NSRR was disestablished and the base was designated as Naval Activity Puerto Rico. Currently NAPR is in caretaker status to preserve the present resources.

SWMU 1, located east of the Navy Lodge, encompasses an area of roughly 116 acres of land (see Figure 2-2). The SWMU is bounded to the north by Kearsage Road leading to the U.S. Customs Pier, Ensenada Honda to the east, estuarine wetlands to the south, and the Navy Lodge and Bowling Alley to the west. Based on previous reports, the Army Cremator Disposal Site operated from the early 1940s until the early 1960s and was the main station landfill during this period. The waste material was disposed of by piling, burning, and compacting (A.T. Kearney, Inc., 1988). According to the Naval Energy and Environmental Support Activity (NEESA), an estimated 100,000 tons of waste including scrap metal, inert ordnance, batteries, tires, appliances, cars, cables, dry cleaning solvent cans, paint cans, gas cylinders, construction debris, dead animals, and residential waste was disposed of at this SWMU (NEESA, 1984). No reliable information exists regarding the amounts of material present in the disposal area that could be hazardous; however, in 1984, an Initial Assessment Study (IAS) team estimated that as much as 1,000 tons of hazardous material could be present (NEESA, 1984).

SWMU 2 is located along Langley Drive, approximately 1,000 feet northeast of the Navy Commissary (see Figure 2-2). The site extends from Langley Drive to an estuarine wetland system bordering the Ensenada Honda and has an estimated length of 1,300 feet in a northeast-southwest direction. This site operated as a landfill from approximately 1939 to 1959 and is documented as having been used for the disposal of both hazardous and non-hazardous wastes (NEESA, 1984). Debris noted during the IAS included partially buried metal and concrete objects, old fuel lines, flexible metal hoses, sample containers containing pellets, steel cables, hardened tar, rubble, and ten to fifteen 55-gallon drums that were corroded. The drum contents, generally consisting of a whitish solid with a green outer crust, were exposed (NEESA, 1984). The IAS team estimated the volume of disposed waste to be approximately 1,700 cubic yards, of which approximately 20,000 pounds could be hazardous

2.2 Terrestrial and Aquatic Habitats

A description of the terrestrial and aquatic habitats occurring within and contiguous to SWMUs 1 and 2 is provided in the sections that follow. As discussed in Section 2.0, the description of habitats relies primarily on literature-based information for Puerto Rico and NAPR, and is supplemented by site-specific observations recorded during the habitat characterization conducted at SWMUs 1 and 2 in May 2000 (see Appendix C).

2.2.1 Terrestrial Habitats

The upland habitat bounded by NAPR is classified as subtropical dry forest (Ewel and Witmore, 1973). Similar to other forested areas of Puerto Rico, this region was previously clear-cut in the early part of the century, primarily for pastureland (Geo-Marine, 1998). After acquisition by the Navy, a secondary growth of thick scrub, dominated by lead tree (*Leucaena spp*.), Christmas tree (*Randia aculeate*), sweet acacia (*Acacia famesiana*), and Australian corkwood (*Sesbania grandiflora*) grew in the previously grazed sections (Geo-Marine, Inc., 1998). Secondary growth communities (upland coastal forest communities and coastal scrub forest communities) exist today throughout the station's undeveloped upland. The secondary growth upland vegetative communities at SWMU 1 are classified as coastal scrub forest and upland coastal forest communities, while the upland vegetative communities at SWMU 2 are classified as upland coastal forest communities (see Figure 2-3).

The upland coastal forest community at SWMU 1 consists of a shrub layer (dominated by lead tree, almacigo [*Bursa simaruba*], and Christmas tree), a tree layer (oxhorn bucida [*Bucida buceras*], basket wiss [*Trichostigma octandrum*], and common guayaba [*Psidium guajava*]), as well as herbaceous areas dominated by *Panicum maximum* (no common name) (Geo-Marine, Inc., 2000). The SWMU's coastal scrub forest community is limited to two stratums (shrub and herbaceous). Lead tree and *Panicum maximum* dominate the shrub and herbaceous stratums, respectively. A tree layer is not present within the coastal scrub forest community (Geo-Marine, Inc., 2000). Identical to the coastal shrub forest community at SWMU 1, the upland coastal forest community at SWMU 2 is limited to a shrub layer and herbaceous layer. The shrub layer is dominated by lead tree, sweet acacia, and bottle wiss (*Capparis flexusa*), while the herbaceous layer is dominated by *Sporobolis indicus* (no common name), *Panicum maximum*, cattle tongue (*Pluchea carolinenis*), and marsh mallow (*Waltheria indicia*).

Cobana negra (*Stahlia monosperma*), a federally threatened tree species, is known to occur between the boundary of black mangrove communities and coastal upland forest communities. This species is also known to occur in coastal forests of southeastern Puerto Rico (Little and Wadsworth, 1964). A single individual has been reported at NAPR. Although the location of the sighting was not documented, NAPR personnel believe the tree is located within the coastal forest community behind the former Navy Exchange store, northwest of SWMU 1 and Langley Drive. Cobana negra was not observed at SWMUs 1 and 2 during the May 2000 habitat characterization.

2.2.2 Aquatic Habitats

Approximately 460 acres at NAPR are covered by palustrine habitat, which includes all freshwater wetlands. These wetlands include wet meadows and marshes dominated by cattails (*Typha spp*.) and grasses (*Panicum spp*. and *Paspalum spp*.) and wet coastal scrub forests. The marine environment surrounding NAPR includes mudflats, mangroves and seagrass beds. Mangroves on NAPR mainly consist of red mangrove (*Rhizophora mangle*), black mangrove (*Avicenia germinans*), and white mangrove (*Laguncularia racemosa*) (Geo-Marine, Inc., 2000 and 2005). Red mangroves tolerate relatively deep water levels, grow in unstable, soft soil, and tolerate a salinity range of 10 to 55 parts per thousand (ppt). They develop large prop roots which usually extend above the water surface. Black and white mangroves generally grow in areas that are not inundated by water. Mangroves on NAPR are natural filters for upland runoff and protect the coastline from storm damage (Lewis, 1986). They also provide habitat for wildlife, fish, and benthic invertebrates. Lewis (1986) reported 112 species of birds that use the NAPR mangroves as habitat for feeding, nesting, and roosting. The red mangrove prop root habitat in Puerto Rico also is used by at least 13 species of fish (including the gray snapper [*Lutijanus griseus*], lane snapper [*Lutijanus synagris*], and gold and black tricolor [*Holocanthus tricolor*]), several crustaceans (including the flat tree oyster [*Isognomon alatus*]), gastropods (including the coffee bean snail [*Melampus coffeus*] and mangrove periwinkle [*Littorina* *angulifera*]), echinoids (including the long-spined sea urchin [*Diadema antillarum*] and pencil sea urchin [*Eucidaris tribuloides*]), sponges (including the fire sponge [*Tedania ignis*]), ascidians (including the black tunicate [*Acsidia nigra*]), and hydroids (including the feathered hydroid [*Halocordyle disticha*]) (Geo-Marine Inc., 2005).

The seagrass beds in eastern Puerto Rico are typical of well developed climax meadows found throughout the tropical Atlantic and Caribbean basin consisting primarily of dense continuous coverage of turtle grass with lesser amounts of manatee grass and a wide diversity of calcareous algae (Reid et al., 2001). Patchy and sparse beds of mixed species, including shoal grass, manatee grass, and paddle grass, occur in localized areas affected and maintained by different wave regimes, substrate type, and turbidity than what is normally found in association with the climax turtle grass meadows.

The nearest open water habitat downgradient from SWMUs 1 and 2 is the Ensenada Honda. As evidenced by Figure 2-3, seagrass beds are prevalent throughout much of the Ensenada Honda, including the area immediately downgradient from SWMUs 1 and 2. Seagrass meadows within the Ensenada Honda are dominated by a nearly continuous cover of turtle grass with a high abundance of calcareous green algae (*Avranvilla spp*., *Ventricaria ventricosa*, *Caulerpa spp*., *Valonia spp*., and *Udotea spp*.) (Reid et al., 2001). The turtle grass climax meadows of the Ensenada Honda represent potential grazing areas for the West Indian manatee (*Trichechas manatus*), a federall endangered species, and the Green Sea Turtle (*Chelonia mydas)*, a federally threatened endangered species in Puerto Rico.

A map showing the spatial relationship of each SWMU to the Ensenada Honda is provided as Figure 2-4. Included on this figure are wetland units identified by the Cowardin Wetland Classification System (Cowardin et al., 1979 [see Figure 2-5]). The wetlands depicted on Figure 2-4 were delineated by Geo-Marine, Inc. in December 1999 from 1993 color infrared and 1998 true color aerial photography. Twenty percent of the wetlands delineated by aerial photography were field checked to verify the accuracy of the delineations. Field verification was based on the 1987 Corps of Engineers wetland delineation manual (United States Army Corps of Engineers [USACE], 1987). As evidenced by Figures 2-3 and 2-4, there are no freshwater wetland units within or contiguous to SWMUs 1 and 2. However, both SWMUs infringe upon an estuarine wetland system (mangroves) bordering the Ensenada Honda. Both red and black mangrove communities are present at SWMUs 1 and 2. The red mangroves occur adjacent to the Ensenada Honda, while black mangroves are located inland between the red mangroves and the coastal upland scrub/forest communities. Specific wetland units located within the estuarine wetland system downgradient from SWMUs 1 and 2 include the following Cowardin classifications: E2SS3 (Estuarine, Intertidal, Scrub-Shrub, Broad-leaved Evergreen), E2US2 (Estuarine, Intertidal, Unconsolidated Shore, Sand), E2US3 (Estuarine, Intertidal, Unconsolidated Shore, Mud), and E2US4 (Estuarine, Intertidal, Unconsolidated Shore, Organic).

2.3 <u>Biota</u>

A description of the biota occurring within Puerto Rico and the landmass encompassed by NAPR is provided in the sections that follow. This description is supplemented by information contained within the habitat characterization report included as Appendix C.

2.3.1 Mammals

A total of 22 terrestrial mammal species are known historically from Puerto Rico; however, all mammals except bats (13 species) have been extirpated (United States Geological Survey [USGS], 1999). None of the bats found on Puerto Rico are exclusive to the island. The West Indian manatee is known to occur in the marine environment surrounding NAPR. As depicted on Figure 2-3 and discussed in Section 2.2.2, seagrass (i.e., turtle grass) beds are located throughout much of the shallow water habitat within the Ensenada Honda. Their locations represent potential feeding habitat for this marine mammal.

Several terrestrial mammals have been introduced into Puerto Rico, including the black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), and mongoose (*Herpestes javanicus*). These nonindigenous mammals have been implicated in the decline of native bird and reptile populations (USGS, 1999 and United States Fish and Wildlife Service [USFWS], 1996).

2.3.2 Birds

A total of 239 bird species are native to Puerto Rico (Raffaele, 1989). This total includes breeding permanent residents and non-breeding migrants. In addition, many nonindigenous bird species have been introduced to Puerto Rico, including the shiny cowbird (*Molothrus bonariensis*) and several parrot species, such as the budgerigar (*Melopsittacus undulates*), orange-fronted parrot (*Aratinga canicularis*), and monk parrot (*Myiopsitta monaqchus*). Of the 239 species native to Puerto Rico, 12 are endemic to the island (Raffaele, 1989).

Numerous native and migratory bird species have been reported at NAPR (Geo-Marine Inc., 1998). A list compiled from literature-based information pre-dating 1990 (see Table 2-1) includes the great blue heron (*Ardea herodias*), snowy egret (*Egretta thula*), little blue heron (*Florida caerulea*), black-crowned night heron (*Nycticorax nycticorax*), belted kingfisher (*Ceryle alcyon*), spotted sandpiper (*Actitis macularia*), greater yellowlegs (*Tringa melanoleauca*), black-bellied plover (*Squatarola squatarola*), clapper rail (*Rallus longirostris*), Royal tern (*Thalasseus maximus*), sandwich tern (*Thalasseus sandvicensis*), least tern (*Stema albifrons*), yellow warbler (*Dendroica petechia*), palm warbler (*Dendroica palmarum*), prairie warbler (*Dendroica discolar*), magnolia warbler (*Dendrocia magnolia*), mourning dove (*Zenaida macroura*), red-legged thrush (*Mimocichla plumbea*), common nighthawk (*Chordeiles minor*), and red-tailed hawk (*Buteo jamaicensis*). Endemic species reported from NAPR include the Puerto Rican lizard cuckoo (*Saurothera vieilloti*), Puerto Rican flycatcher (*Myiarchus antillarum*), Puerto Rican woodpecker (*Malanerpes portoricensis*), Puerto Rican emerald (*Chlorostilbon maugaeus*), and yellow-shouldered blackbird (*Agelaius xanthomus*).

The yellow-shouldered blackbird is a federally endangered species. One of the principal reasons for the status of this species is attributed to parasitism by the nonindigenous shiny cowbird, which lays its eggs in blackbird nests and sometimes punctures the host's eggs (USFWS, 1983). Other factors contributing to the status of this species include nest predation by the introduced black rat, Norway rat, and mongoose, as well as habitat modification and destruction (USFWS, 1996). The entire land area of NAPR was declared critical habitat for the yellow-shouldered blackbird in 1976; however, a 1980 agreement with the USFWS exempted certain areas from this categorization (Geo-Marine Inc., 1998). SWMUs 1 and 2 are located within the critical habitat designation. A study conducted by the Naval Facilities Engineering Command (NFESC, 1996) reported that the mangrove forests surrounding NAPR should be considered the most important nesting habitats for the yellow-shouldered blackbird. A survey conducted by the Puerto Rico Department of Natural Resources (PRDNR, 2002) reported fifteen yellow-shouldered blackbirds (including five juveniles) at NAPR. At the time of the survey, the birds were using structures at the NAPR airport for resting cover. Although nesting pairs were not observed (the survey was not conducted during the breeding season), the airport structures contained several inactive nests. The inactive nests and juvenile birds indicate that a small breeding population is present at NAPR. Yellow-shouldered blackbirds were not observed within the coastal scrub forest or upland coastal forest communities within SWMUs 1 and 2 (Geo-Marine Inc., 2000).

Other federally listed bird species that have been reported at NAPR or have the potential to occur are the brown pelican (*Pelecanus occidentalis occidentalis*), roseate tern (*Sterna dougallii dougallii*), and the piping plover (*Charadrius melodus*) (Geo-Marine Inc., 1998). The brown pelican appears to be a common seasonal resident at NAPR and in the surrounding coastal waters; however, no critical habitat is designated for the species at NAPR, on adjacent cays, or in nearby coastal waters (Geo-Marine Inc., 2005). The occurrence of the piping plover at NAPR is expected to be limited to vagrants as no piping plover observations were recorded at NAPR during the 1990's or during turtle nesting surveys conducted in 2002 and 2004. In addition, no critical habitat for this species has been designated in Puerto Rico (Geo-Marine, Inc., 2005). No historic evidence is available to indicate whether the roseate tern has ever nested at NAPR as no observations have been recorded in or over the coastal waters adjacent to NAPR (Geo-Marine Inc., 2005). Identical to the brown pelican and piping plover, no critical habitat has been designated for this species at NAPR.

Specific bird species observed within the vegetative communities at SWMUs 1 and 2 are listed in the habitat characterization report (see Appendix C). Species common to both SWMUs include the red-tailed hawk, yellow warbler, Puerto Rican woodpecker, loggerhead kingbird (*Tyannus caudifasciatus*), zenaida dove, and pearly-eyed thrasher (*Margarops fuscatus*). An active Wilson's plover (*Charadrius wilsonia*) nest was observed within the black mangrove community downgradient from SWMU 1.

2.3.3 Reptiles and Amphibians

A total of 23 amphibians and 47 reptiles are known from Puerto Rico and the adjacent waters (USGS, 1999). Fifteen of the amphibians and 29 of the reptiles are endemic, while four amphibian species and three reptilian species have been introduced (USGS, 1999). Puerto Rico's native amphibian species include 16 species of tiny frogs commonly called coquis. On the coastal lowlands, almost all coqui species are arboreal. The only amphibians listed under provisions of the Endangered Species Act of 1973 are the Puerto Rican ridge-headed toad (*Peltophryene lemur*) and the golden coqui (*Eleutherodactylus jasperi*). Both species are listed as threatened. The distribution of the golden coqui is restricted to areas of dense bromeliad growth. All specimens to date have been collected from a small semicircular area of a 6-mile radius south of Cayeye (approximately 30 miles southwest of NAPR), generally at elevations above 700 meters (USFWS, 1984). The Puerto Rican ridge-headed toad occurs at low elevations (below 200 meters) where there is exposed limestone or porous, well drained soil offering an abundance of fissures and cavities (USFWS, 1987). A single large population is known to exist from the southwest coast in Guánica Commonwealth Forest, and a small population is believed to survive on the north coast near Quebradillas, Arecibo, Barceloneta, Vega Baja, and Bayamón (USFWS, 1987). It has also been collected on the southeastern coastal plain near Coamo (USFWS, 1987). Given the habitat preferences and locations of known occurrences, these two species are not expected to occur at NAPR.

Puerto Rico's native reptilian species include 31 lizards, 8 snakes, 1 freshwater turtle, and 5 sea turtles (USGS, 1999). Of the five sea turtles, only the green sea turtle, hawksbill sea turtle (*Eretmochelys imbricata*), and loggerhead sea turtle (*Dermochelys coriacea*) nest within Puerto Rico. These three sea turtles, the leatherback sea turtle (*Caretta caretta*), and the Puerto Rican boa (*Epicrates inornatus*) represent the reptilian species listed under the provisions of the Endangered Species Act of 1973 (USGS, 1999). Given the presence of seagrass within the Ensenada Honda, this surface water body represents potential feeding habitat for the green sea turtle (see Section 3.2.2.2.1 for a detailed description of sea turtle life history information).

Four Puerto Rican boa sitings were reported at NAPR prior to 1999 and an additional four occurrences were reported between 2001 and 2003 (Geo-Marine Inc., 2005). However, no boas were observed during 211 man-hours of surveys conducted within potential boa habitat in 2004 (Geo-Marine Inc., 2005). The Puerto Rican boa uses a variety of habitats but is most commonly found in Karst forest habitat (forested limestone hills). Based on the absence of preferred habitat, there is low probability of occurrence of this species at SWMUs 1 and 2.

Several lizard species were observed within the vegetative units at and contiguous to SWMUs 1 and 2 during the May 15 to May 19, 2000 habitat characterization, including the crested anole (*Anolis cristatellus*), *Anolis stratulus* (no common name), and *Anolis pulchellus* (no common name). Two amphibian species (i.e., frogs) were also observed within the upland coastal forest community at SWMU 2 (*Eleutherodactylus spp*. [no common name] and the white-lipped frog [*Leptodactylus albilabris*]).

2.3.4 Fish and Aquatic Invertebrates

A diverse fish and invertebrate community can be found in the marine environment surrounding NAPR. This can be attributed to the varied habitats that include marine and estuarine open water habitat, mud flats, seagrass beds, and mangrove forests. The fish community is represented by stingrays, herrings, groupers, needlefish, mullets, barracudas, jacks, snappers, grunts, snooks, lizardfishes, parrotfishes, gobies, filefishes, wrasses, damselfishes, and butterflyfish (Geo-Marine Inc., 1998). The benthic invertebrate community includes sponges, corals, anemones, sea cucumbers, sea stars, urchins, and crabs. As discussed in Section 2.2.2, the red mangrove prop root habitat in Puerto Rico is used by numerous species of fish and invertebrates.

3.0 BASELINE RISK ASSESSMENT PROBLEM FORMULATION

The baseline ERA problem formulation (Step 3b of the Navy ERA process) is a revision of the screening-level problem formulation developed in Step 1 of the ERA process (Baker, 2006a). This revised problem formulation consists of an evaluation of the fate and transport and potential toxicity of the potential ecological risk drivers identified in Step 3b of the baseline ERA (Baker, 2006a) and presents a refined conceptual model. The conceptual model includes a discussion of exposure pathways, assessment endpoints, and risk questions specific to chemical-receptor combinations requiring further evaluation.

3.1 Screening-Level Ecological Risk Assessment and Step 3a of the Baseline Ecological Risk Assessment: Identification of Potential Ecological Risk Drivers

The Navy ERA process consists of eight steps organized into three tiers and represents a clarification and interpretation of the eight-step ERA process outlined in the USEPA ERA guidance for the Superfund program (United States Environmental Protection Agency [USEPA], 1997). Tier 1 of the Navy ERA process represents the screening-level ERA:

- Screening-level problem formulation and ecological effects evaluation (Step 1).
- Screening-level exposure estimate and risk calculation (Step 2).

Under Navy policy, if the results of Step 1 and Step 2 (Tier 1 screening-level ERA) indicate that, based on a set of conservative exposure assumptions, there are chemicals present in environmental media that may present a risk to receptor species/communities, the ERA process proceeds to the baseline ERA. According to Superfund guidance (USEPA, 1997), Step 3 represents the problem formulation phase of the baseline ERA. Under Navy policy, the baseline ERA is defined as Tier 2, and the first activity under Tier 2 is Step 3a. Step 3a precedes the baseline risk assessment problem formulation (Step 3b). In Step 3a, the conservative exposure assumptions applied in Tier 1 are refined and risk estimates are recalculated using the same preliminary conceptual model. The evaluation of risks in Step 3a may also include consideration of background data, chemical bioavailability, and the frequency of detection. If the re-evaluation of the conservative exposure assumptions does not support an acceptable risk determination, the site continues in the baseline ERA process (Step 3b baseline ERA problem formulation).

A screening-level ERA and Step 3a of the baseline ERA were conducted at SWMUs 1 and 2 (Baker, 2006a). The screening-level ERA (Steps 1 and 2) and Step 3a of the baseline ERA included an evaluation of the terrestrial, estuarine wetland, and open water habitat (Ensenada Honda) associated with each SWMU. Chemicals identified as potential ecological risk drivers and recommended for additional evaluation in Step 3b of the baseline ERA are summarized in Table 1-1 and are discussed within the sections that follow.

3.1.1 SWMU 1

Based on the evaluation of chemicals detected in surface soil, antimony (Sb), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), tin (Sn), zinc (Zn), 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were identified as potential ecological risk drivers for lower trophic level terrestrial receptor communities (i.e., terrestrial plant and invertebrate communities). The evaluation of chemicals detected in subsurface soil identified 4,4'-DDE and 4,4'-DDT as potential ecological risk drivers for terrestrial invertebrate and plant communities. Surface and subsurface soil analytical data for chemicals identified as potential ecological risk drivers are summarized in Tables 3-1 and 3-2, respectively. Detections above soil screening values also are depicted on Figures 3-1 (surface soil) and 3-2 (subsurface soil). As evidenced by Tables 3-1 and 3-2 and Figures 3-1 and 3-2, maximum 4,4'-DDE and 4,4'-DDT concentrations occurred within surface soil.

In addition to the evaluation of lower trophic level community exposures, the screening-level ERA and Step 3a of the baseline ERA also evaluated potential avian food web exposures to chemicals in SWMU 1 surface and subsurface soil. Cadmium, lead, mercury, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in surface soil were identified as potential ecological risk drivers for avian omnivore food web exposures. Lead in surface soil also was identified as a potential ecological risk driver for avian herbivore food web exposures. Surface soil analytical data for chemicals identified as potential ecological risk drivers for avian terrestrial food web exposures are summarized in Table 3-1. Potential ecological risk drivers were not identified for avian food web exposures to chemicals in subsurface soil and no additional evaluation of subsurface soil food web exposures was recommended.

Potential ecological risk drivers were not identified for lower trophic level aquatic receptor community exposures to chemicals in estuarine wetland or Ensenada Honda surface water and sediment and no further evaluation was recommended. Additional evaluation also was not recommended for avian food web exposures to chemicals detected in estuarine wetland sediment. However, arsenic, mercury, and selenium (Se) in open water sediment were identified as potential ecological risk drivers for West Indian manatee aquatic food web exposures (maximum hazard quotient [HQ] values = 28.2 for arsenic, 3.31 for mercury, and 3.58 for selenium). Cadmium, copper, and zinc also were identified as potential ecological risk drivers for West Indian manatee food web exposures based on their bioaccumulative potential and maximum HQ values derived using toxicity reference values that reflect differences between the test species and the West Indian manatee, as well as the endangered status of this potential receptor (maximum HQ values = 5.66 for cadmium, 1.72 for copper, and 3.43 for zinc). Open water sediment analytical data for chemicals identified as potential ecological risk drivers for West Indian manatee food web exposures are summarized in Table 3-3.

3.1.2 SWMU 2

Based on the evaluation of chemicals detected in surface soil, antimony, copper, lead, mercury, and zinc were identified as potential ecological risk drivers for terrestrial invertebrate and plant communities. The evaluation of chemicals detected in subsurface soil also identified antimony, copper, lead, mercury, and zinc as potential ecological risk drivers for terrestrial invertebrate and plant communities. Surface and subsurface soil analytical data for chemicals identified as potential ecological risk drivers for lower trophic level terrestrial receptor communities are summarized in Tables 3-4 and 3-5, respectively. Detections above soil screening values also are depicted on Figures 3-3 (surface soil) and 3-4 (subsurface soil).

In addition to the evaluation of lower trophic level community exposures, the screening-level ERA and Step 3a of the baseline ERA also evaluated potential avian food web exposures to chemicals in SWMU 2 surface and subsurface soil. Lead, mercury, and zinc in surface soil were identified as potential ecological risk drivers for avian omnivore and avian herbivore terrestrial food web exposures. Copper, lead, and zinc in subsurface soil also were identified potential ecological risk drivers for avian omnivore and avian herbivore terrestrial food web exposures. Surface and subsurface soil analytical data for chemicals identified as potential ecological risk drivers for avian terrestrial food web exposures are summarized in Tables 3-4 and 3-5, respectively.

Copper, lead, and zinc in estuarine wetland sediment were identified as potential ecological risk drivers for benthic invertebrates. SWMU 2 estuarine wetland sediment analytical data for copper, lead, and zinc are summarized in Table 3-6. Ecological risk driver detections above sediment screening values also are depicted on Figure 3-5. In addition to the evaluation of benthic invertebrates, the screening-level ERA and Step 3a of the baseline ERA also evaluated potential avian aquatic food web exposures to chemicals in SWMU 2 estuarine wetland sediment. Based on this evaluation, lead and mercury were identified as potential ecological risk drivers for avian aquatic invertebrate consumers (see Table 3-6 for a summary of available SWMU 2 estuarine wetland sediment mercury analytical data).

Potential ecological risk drivers were not identified for lower trophic level aquatic receptor community exposures to chemicals detected in Ensenada Honda surface water or sediment and no further evaluation was recommended. However, arsenic, mercury, and selenium in open water sediment were identified as potential ecological risk drivers for West Indian manatee aquatic food web exposures (maximum No Observed Adverse Effects Level [NOAEL]-based HQ values = 35.6 for arsenic, 1.71 for mercury, and 1.52 for selenium). Cadmium, copper, lead, and zinc also were identified as potential ecological risk drivers for West Indian manatee food web exposures based on their bioaccumulative potential and maximum HQ values derived using toxicity reference values that reflect differences between the test species and the West Indian manatee, as well as the endangered status of this potential receptor (maximum NOAEL-based HQ values = 3.43 for cadmium, 1.26 for copper, 4.56 for lead, and 3.11 for zinc). Open water sediment analytical data for arsenic, cadmium, copper, lead, mercury, selenium, and zinc are summarized in Table 3-7.

3.2 Refined Conceptual Model

Information on the habitat features of the site, the fate and transport of potential ecological risk drivers, and the key exposure pathways, routes, and receptor groups are used to refine the preliminary conceptual model developed in Step 1 of the ERA. A graphical representation of the conceptual models for SWMUs 1 and 2 are presented on Figures 3-6 and 3-7, respectively. These figures illustrate the primary functional components of the terrestrial and aquatic ecosystems at each SWMU. The models have been revised to reflect the results of the screening-level ERA and Step 3a of the baseline ERA and focus on the contaminant-receptor combinations where the potential for unacceptable risk has been identified. Components of each conceptual model are described in the sections that follow.

3.2.1 Contaminant Fate and Transport and Toxicity Evaluation

The sections that follow present an evaluation of the fate and transport of chemicals identified as potential ecological risk drivers by the screening-level ERA and Step 3a of the baseline ERA: antimony, arsenic, cadmium, copper, lead, mercury, selenium, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT (Baker, 2006a). A toxicity evaluation is also presented for each chemical. For a given chemical, the toxicity evaluation focuses on those receptors/receptor groups potentially at risk.

3.2.1.1 Antimony

Antimony and its compounds are naturally present in the earth's crust. Releases to the environment occur from natural processes (e.g., volcanic eruptions). However, most of the antimony released to the environment is from anthropogenic activities, including metal smelting and refining, coal combustion, and refuse incineration (Agency for Toxic Substances and Disease Registry [ATSDR], 1992a.

Antimony displays four oxidation states: Sb^{3-}, Sb^{0}, Sb^{3+}, and Sb^{5+}. The +3 and +5 oxidation states are the most common and stable. Little is known of the adsorptive behavior of antimony, its compounds, and ions. The binding of antimony to soil and sediment is primarily correlated with the iron, manganese, and aluminum content as it co-precipitates with hydroxylated oxides of these elements (ATSDR, 1992a). Some forms of antimony may bind to inorganic and organic ligands. Mineral forms are unavailable for binding. Some studies suggest that antimony is fairly mobile under diverse environmental conditions, while others suggest that it is strongly adsorbed to soil (ATSDR, 1992a).

Uptake from soil by plants is minor and appears to be correlated with the amount of available antimony (that which is soluble or easily exchangeable). Studies have shown that antimony does not biomagnify from lower to higher trophic levels in terrestrial food chains (ATSDR, 1992a).

As a natural constituent of soil, antimony is transported into streams and waterways from weathering of soil as well as from anthropogenic sources. The forms of antimony and the chemical and biochemical process that occur in the aquatic environment are not well understood. Antimony in both aerobic freshwater and seawater is largely in the +5 oxidation state, although antimony in the +3 oxidation state does occurs in these waters. Under reducing conditions, trivalent species such as $Sb(OH)_3$, $Sb(OH)_4^{1-}$, and $Sb_2S_4^{4-}$ may be significant (Andreae and Froelich, 1984). Antimony can be reduced and methylated by microorganisms in the aquatic environment and become mobilized (Andreae et al., 1983 and Austin and Millward, 1988). This reaction is most likely to occur in reducing environments, such as bed sediments. Antimony does not appear to bioconcentrate appreciably in fish and aquatic organisms (ATSDR, 1992a).

Antimony in SWMU 1 surface soil and SWMU 2 surface and subsurface soils has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 5.0 milligram per kilogram (mg/kg): Toxicological benchmark for terrestrial plants (Efroymson et al., 1997a)

- 78 mg/kg: Ecological Soil Screening Level (Eco SSL) for soil invertebrates (USEPA, 2005a)

3.2.1.2 Arsenic

Arsenic is a naturally occurring element which exists mainly in rock or soil and cycles biogeochemically via oxidation and reduction (Eisler, 1988a). Arsenate (pentavalent, As^{5+}) is the predominant inorganic form in oxygenated water (where it will be chemically bound to soil or sediment particles), while arsenite (trivalent, As^{3+}) is the predominant arsenic form under anaerobic conditions (USEPA, 1981). Arsenite is water soluble and therefore more mobile and is considered to be the more toxic form (USEPA, 1999). Arsenic is readily adsorbed onto sediments with high organic matter and those with high clay content, sulphur, manganese, iron oxides, and aluminum hydroxides (USEPA, 1999 and MacDonald, 1994). Adsorption and release also depend on the arsenic concentration, pH, oxidation-reduction potential, temperature, salinity, and the ionic concentration of other compounds (ATSDR, 2005a and Eisler, 1988a). Transport within the aquatic environment for bound arsenic, therefore, is largely a function of suspended sediment dynamics or larger-scale erosive events. Changes in the oxidative state and/or biological interactions can release arsenic back into the water column.

In soils, arsenic uptake is dependent upon the form of arsenic available and the physical and chemical properties of the soil, including organic carbon and clay content. Higher organic material and clay content favor binding within the soil to immobile forms, and thus less potential for uptake (USEPA, 1999). Arsenic is generally not bioavailable to aquatic organisms under aerobic conditions (MacDonald, 1994). Arsenic may be bioaccumulated by lower trophic level organisms; however, data does not indicate that significant biomagnification occurs (USEPA, 1999), especially in aquatic food chains. Once within the mammalian body, arsenic readily moves through the body and does not preferentially accumulate in any organs (USEPA, 1999). Arsenic is metabolized (methylated) readily in the liver of mammals to less toxic forms and is subsequently rapidly eliminated (USEPA, 1999). As such, the potential for bioaccumulation in mammalian tissues is minimal. Identified impacts to aquatic organisms include growth, reproduction, behavioral, mutagenic, and carcinogenic effects (MacDonald, 1994).

Arsenic in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. The manatee is an herbivorous species, which feeds primarily on seagrass. Uptake and adsorption of metals in general by submerged aquatic vegetation is influenced by salinity gradients along an individual plant (roots to stems), photosynthetic rates, and temporal periodicity, including growing season (Wasserman and Wasserman, 2002). A study comparing metals concentrations in aquatic plant material at the US Navy bombing range at Vieques and a neighboring reference location in Puerto Rico found arsenic concentrations of 0.61 micrograms per gram (ug/g; dry weight) in manatee grass at the bombing range following the cessation of bombing activities in 2004 and 1.04 ug/g (dry weight) in manatee grass at the reference area in 2003/2004 (Massol-Deyá et al., 2005). A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of arsenic ingestion by mammals. A 3-generation study investigating the reproductive effects of arsenite on mice determined a lowest observed adverse effects level (LOAEL) of 1.26 milligrams per kilogram-body weight per day (mg/kg-BW/day) (Sample et al., 1996). At this dose (oral in water plus incidental in food), mice displayed declining litter sizes. A chronic NOAEL of 0.126 mg/kg-BW/day was estimated by applying an uncertainty factor of 10 to the chronic LOAEL (Sample et al., 1996). This study forms the basis of the NOAEL and LOAEL values developed for the West Indian manatee dietary exposures to arsenic in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.3 Cadmium

Cadmium is a naturally occurring element found in phosphate rock. It is used in many industrial applications, including alloy manufacturing, batteries, plastics, paints, fuels, and agricultural products (e.g., fertilizers). It exhibits low vapor pressure and is found in two valence states: Cd^0 or Cd^{2+}. Cadmium is persistent in the environment and is generally stable in soil (ATSDR, 1999a). Terrestrial transformation processes include precipitation, complexation, ion exchange, and dissolution (USEPA, 1999). In the aquatic environment, cadmium is found as a component of organic compounds and as inorganic sulfides, oxides, and halides. Photodegradation and biological degradation are generally not important. Cadmium sorbs to sedimentary particles and precipitates with aluminum, manganese, and iron oxides (MacDonald, 1994 and ATSDR, 1999a). The bioavailability of cadmium is dependent on the chemical and physical properties of the aquatic environment, including redox potential, water hardness, and pH (MacDonald, 1994). The presence of acid volatile sulfide (AVS) in sediment (a complexing agent, found under reducing conditions) has been identified as an important factor governing the bioavailability of cadmium (Di Toro et al., 1991).

Freshwater aquatic species are generally more sensitive to the toxic effects of cadmium than marine species; toxicity in freshwater environments is inversely proportional to the water hardness (USEPA, 1999). Survival, growth, reproduction, and behavioral impacts have been noted for marine invertebrates (MacDonald, 1994). Diatoms and aquatic plants also show impaired growth and development. Cadmium can cross the placental barrier in mammals and is a reproductive toxin in fish and other aquatic life. Other adverse effects in upper trophic level aquatic organisms include interference with the kinetics of other metals, decreased oxygen utilization, and bone marrow, heart, kidney, and vascular impacts (USEPA, 1999). Though elimination from the body does occur, cadmium can concentrate in tissues and thus can accumulate in food chains. An inverse relationship between cadmium uptake via dietary exposures and uptake of iron and calcium has been noted (USEPA, 1999). Vertebrates tend to accumulate cadmium in the kidney and liver (Eisler, 1985).

Cadmium in SWMU 1 surface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 4 mg/kg: Toxicological benchmark for terrestrial plants (Efroymson et al., 1997a)
- 20 mg/kg: Toxicological benchmark for earthworms (Efroymson et al., 1997b)
- 32 mg/kg: Eco Soil Screening level (SSL) for terrestrial plants (USEPA, 2005b)
- 140 mg/kg: Eco SSL for soil invertebrates (USEPA, 2005b)

Cadmium in SWMU 1 surface soil also has the potential to impact terrestrial avian omnivores via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of cadmium ingestion by birds. A 90-day study using mallard ducks indicated that an oral dose of 1.45 mg/kg-BW/day caused no impact on reproduction (egg production; Sample et al., 1996). This dose was considered a chronic NOAEL. Adverse reproductive effects occurred at a dose of 20 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for the terrestrial avian omnivore dietary exposures to cadmium in SWMU 1 surface soil (see Section 4.4).

Finally, cadmium in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. The manatee is an herbivorous species, which feeds primarily on seagrass. A study comparing metals concentrations in aquatic plant material at the US Navy bombing range at Vieques and a neighboring reference location in Puerto Rico found cadmium concentrations of 0.28 ug/g (dry weight) in manatee grass at the bombing range while it was active in 2001, 0.15 ug/g (dry weight) in manatee grass after the cessation of bombing activities in 2004, and 0.28 ug/g (dry weight) in manatee grass at the reference area in 2001 and 2003/2004 (Massol-Deyá et al., 2005). A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of cadmium ingestion by mammals. A 6-week study using rats indicated that a dose (gavage) of 1.0 mg/kg-BW/day caused no reproductive impairment (Sample et al., 1996). This dose was considered a chronic NOAEL. Adverse reproductive (fetal) effects occurred at a dose of 10 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for West Indian manatee food web exposures to cadmium in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.4 Copper

Copper is a common metallic element found in crustal rocks and minerals. Natural sources of copper in the environment include weathering of copper-bearing minerals, copper sulfides, and native copper. Anthropogenic sources include corrosion of brass and copper pipe by acidic waters, the use of copper compounds as aquatic algicides, runoff and groundwater contamination from agricultural uses of copper as fungicides, and atmospheric fallout from industrial sources.

Copper exists in four oxidation states: Cu^{0}, Cu^{1+}, Cu^{2+}, and Cu^{3+} (Eisler, 1998a). Copper's movement in soil is determined by a host of physical and chemical interactions with the soil components. In general, copper will absorb to organic matter, carbonate minerals, clay minerals, or hydrous iron and manganese oxides (ATSDR, 2004). Sandy soils with low pH have the greatest potential for leaching. The cupric ion (Cu^{2+}) is the one generally encountered in water and it is the most readily available and toxic inorganic species of copper. Toxicity in freshwater systems is inversely proportional to water hardness. Copper may form associations with organic matter and precipitates of hydroxides, phosphates, and sulfides. Formation of these complexes tends to facilitate transport to sediments. Bioavailabilty in sediment is controlled by the degree of complexation with AVS and adsorption to organic matter (USEPA, 2000a). Copper is an essential micronutrient, and, therefore, is readily accumulated by aquatic organisms. However, no evidence exists to suggest that copper is biomagnified in aquatic ecosystems (Jaagumagi, 1990).

Copper is taken up by mammals primarily through dietary exposure. Most organisms retain only a small proportion of copper ingested with their diet. Once ingested, copper travels through the gastrointestinal tract, where some of it is absorbed into the blood and becomes associated with plasma albumin and amino acids. Albumin-bound copper is eventually transported to the liver where 80 percent is bounded to metallothionein, with the remainder incorporated into enzyme compounds. In mammals, copper is excreted via the bile.

Copper in SWMU 1 surface soil and SWMU 2 surface and subsurface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 50 mg/kg: Toxicological threshold for earthworms (Efroymson et al., 1997b)
- 100 mg/kg: Toxicological threshold for terrestrial plants (Efroymson et al., 1997a)

Copper in SWMU 2 estuarine wetland sediment also has the potential to impact aquatic invertebrates (i.e., benthic macroinvertebrates). Available literature-based toxicological benchmarks for aquatic invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 16 mg/kg: Freshwater Lowest Effects Level (LEL) (Persaud et al., 1993)
- 18.7 mg/kg: Marine Threshold Effects Level (TEL) (MacDonald, 1994)
- 31.6 mg/kg: Consensus-based freshwater Threshold Effect Concentration (TEC) (MacDonald et al., 2000)
- 34 mg/kg: Marine and estuarine Effects Range-Low (ER-L) value (Long et al., 1995)
- 75 mg/kg: Freshwater Severe Effect Level (SEL) (Persaud et al., 1993)
- 108 mg/kg: Marine Probable Effect Level (PEL) (MacDonald, 1994)
- 149 mg/kg: Consensus-based freshwater Probable Effect Concentration (PEC) (MacDonald et al., 2000)

- 270 mg/kg: Marine and estuarine Effects Range-Median (ER-M) value (Long et al., 1995)
- 390 mg/kg: Marine Apparent Effects Threshold (AET) (Buchman, 1999)

In addition to lower trophic level terrestrial and aquatic receptor groups, copper in SWMU 2 subsurface soil has the potential to impact terrestrial avian herbivores and omnivores. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of cadmium ingestion by birds. A 90-day study using chicks indicated that a dose of 47 mg/kg-BW/day (oral in diet) caused no effect on survival and growth (Sample et al., 1996). This dose was considered a chronic NOAEL. Survival and growth was impaired at a dose of 20 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for avian dietary exposures to copper in SWMU 2 subsurface soil (see Section 4.4).

Finally, copper in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. The manatee is an herbivorous species, which feeds primarily on seagrass. A study comparing metals concentrations in aquatic plant material at the US Navy bombing range at Vieques and a neighboring reference location in Puerto Rico found copper concentrations of 30.48 ug/g (dry weight) in manatee grass at the bombing range while it was active in 2001, 17.42 ug/g (dry weight) in manatee grass following the cessation of bombing activities in 2004, and 15.34 ug/g (dry weight) and 12.16 ug/g (dry weight) in manatee grass at the reference area in 2001 and 2003/2004, respectively (Massol-Deyá et al., 2005). A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of copper ingestion by mammals. A one-year reproductive study using mink indicated that a dose (oral in diet) of 11.7 mg/kg-BW/day caused no impairment on kit survival (Sample et al., 1996). This dose was considered a chronic NOAEL. Adverse effects on kit survival occurred at a dose of 15.14 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for West Indian manatee dietary exposures to copper in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.5 Lead

Lead exists in three oxidation states: elemental (Pb^0), monovalent (Pb^+), and tetravalent (Pb^{4+}). In the environment, lead primarily exists as Pb^{2+}. Lead is dispersed throughout the environment primarily as the result of anthropogenic activities. Anthropogenic sources include mining and smelting of ore, manufacture of lead-containing products, combustion of coal and oil, and waste incineration. Many anthropogenic sources of lead, most notably leaded gasoline, lead-based paint, lead solder in food cans, lead-arsenate pesticides, and shot and sinkers, have been eliminated or strictly regulated due to lead's persistence and toxicity (ATSDR, 2005b).

The fate of lead in soil is affected by the adsorption at mineral interfaces, the precipitation of sparingly soluble solid forms of the compound, and the formation of relatively stable organic-metal complexes with soil organic matter (ATSDR, 2005b). These processes are dependent on such factors as soil pH, soil type, particle size, organic matter content, the presence of inorganic colloids and iron oxides, and cation exchange capacity. Most lead is retained strongly in soil, and very little is transported through runoff to surface water or leaching to groundwater except under acidic conditions; however, lead may enter surface waters as a result of erosion of lead-containing soil particles.

Lead exists in three forms in water: (1) dissolved (e.g., Pb^{2+}, $PbOH^{1+}$, $PbCO_3$), which generally results from atmospheric deposition runoff; (2) dissolved bound (e.g., colloids or strong complexes); and (3) particulate (Eisler, 1998b). Particulate and bound forms are common in urban runoff and ore-mining effluents. Lead is most soluble and bioavailable under conditions of low pH, low organic content, low, concentrations of suspended sediments, and low concentrations of the salts of calcium, iron, manganese, zinc, and cadmium (Eisler, 1998b). Common forms of dissolved lead are lead sulfate, lead chloride, lead hydroxide, and lead carbonate, but the distribution of salts is highly dependent on the pH of the water. The speciation of lead differs in fresh water and sea water. In fresh water, lead may partially exist as the divalent cation (Pb^{2+}) at pH values below 7.5, but complexes with dissolved carbonate to form insoluble $PbCO_3$ under alkaline conditions (ATSDR, 2005b). Lead chloride and lead carbonate are the primary complexes formed in seawater.

Most lead entering water is precipitated to sediment in the form of carbonate and hydroxide complexes. Factors affecting the degree of sorption in sediments include pH, organic carbon content, cation exchange capacity, and the presence of other constituents such as metal oxides, aluminum silicates, carbonates, and AVS. Lead can be mobilized and released from sediment with sudden pH decreases or ionic composition changes. Sorption is higher in sediments containing clay, and lower in sediments containing a higher percentage of sand (Eisler, 1998b). The amount of bioavailable lead in sediment is controlled, in large part, by the concentration of AVS and organic matter. Some Pb^{2+} in sediment may be transformed to tetralkyl lead compounds, including tetramethyl lead, through chemical and microbial processes. However, most organolead compounds result from anthropogenic inputs. In water, tetralkyl lead compounds are subject to photolysis and volatilization. Lead is accumulated by aquatic organisms equally from water and through dietary exposure (USEPA, 2000a). Lead does not biomagnify to a great extent in food chains, although accumulation by plants and animals has been extensively documented (Eisler, 1998b).

Lead in SWMU 1 surface soil and SWMU 2 surface and subsurface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 50 mg/kg: Toxicological threshold for terrestrial plants (Efroymson et al., 1997a)
- 120 mg/kg: Eco SSL for terrestrial Plants (USEPA, 2005c)
- 500 mg/kg: Toxicological threshold for earthworms (Efroymson et al., 1997b)
- 1,700 mg/kg: Eco SSL for soil invertebrates (USEPA, 2005c)

Lead in SWMU 2 estuarine wetland sediment also has the potential to impact aquatic invertebrates (i.e., benthic macroinvertebrates). Available literature-based toxicological benchmarks for aquatic invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 30.2 mg/kg: Marine TEL (MacDonald, 1994)
- 31 mg/kg: Freshwater LEL (Persaud et al., 1993)
- 35.8 mg/kg: Consensus-based freshwater TEC (MacDonald et al., 2000)
- 47 mg/kg: Marine and estuarine ER-L value (Long et al., 1995)

- 112 mg/kg: Marine PEL (MacDonald, 1994)
- 128 mg/kg: Consensus-based freshwater PEC (MacDonald et al., 2000)
- 218 mg/kg: Marine and estuarine ER-M value (Long et al., 1995)
- 250 mg/kg: Freshwater SEL (Persaud et al., 1993)
- 400 mg/kg: Marine AET (Buchman, 1999)

In addition to lower trophic level terrestrial and aquatic receptor groups, lead in SWMU 1 surface soil has the potential to impact terrestrial avian herbivores and omnivores via dietary (food web) exposures. Lead in SWMU 2 surface soil also has the potential to impact terrestrial avian omnivores, while lead in SWMU 2 subsurface soil has the potential to impact terrestrial avian herbivores and onminvores. In addition, lead in SWMU 2 estuarine wetland sediment also has the potential to impact aquatic avian invertebrate consumers via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of lead ingestion by birds. A 12-week study using Japanese quail indicated that a dose of 1.13 mg/kg-BW/day (oral in diet) caused no effect on egg hatching success (Sample et al., 1996). This dose was considered a chronic NOAEL. Egg hatching success was impaired at a dose of 11.3 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for terrestrial avian dietary exposures to lead in SWMU 2 surface and subsurface soil and estuarine wetland sediment (see Section 4.4).

Finally, the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a) indicated that lead in SWMU 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. The manatee is an herbivorous species, which feeds primarily on seagrass. A study comparing metals concentrations in aquatic plant material at the US Navy bombing range at Vieques and a neighboring reference location in Puerto Rico found lead concentrations of 33.32 ug/g (dry weight) in manatee grass at the bombing range while it was active in 2001, 8.14 ug/g (dry weight) in manatee grass following the cessation of bombing activities in 2004, and 5.88 ug/g (dry weight) and 2.23 ug/g (dry weight) in manatee grass at the reference area in 2001 and 2003/2004, respectively (Massol-Deyá et al., 2005). A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of lead ingestion by mammals. A 3-generation reproductive study conducted with rats indicated that a dose (oral in diet) of 8.0 mg/kg-BW/day caused no impairment on reproduction (Sample et al., 1996). This dose was considered a chronic NOAEL. Adverse effects on reproductive indices occurred at a dose of 80 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for West Indian manatee dietary exposures to lead in SWMU 2 open water sediment (see Section 4.4).

3.2.1.6 Mercury

Mercury is a naturally occurring element found in cinnabar, a sulfide mineral. Industrial applications and uses include paint manufacturing, paper industry, electrical equipment, batteries, thermometers, and at one time, pesticides (MacDonald, 1994). Transport pathways to the aquatic environment include waste dumping and incineration, mining, smelting, and coal combustion. It is persistent in the environment and is found in three states naturally, Hg^0 (metallic/elemental), Hg^{1+} (mercurous), and Hg^{2+} (mercuric [Hg(II)]). Elemental mercury is unique among metals in being liquid at ambient temperature and being quite volatile. It partitions strongly to air in the environment and is not found in nature as a pure, confined liquid. Of the two ionic forms of mercury (mercurous and mercuric mercury), the mercuric form is more environmentally stable, and therefore predominates.

Mercuric mercury is the dominant form in surface water (ATSDR, 1999b). In sediment, mercury is generally found adsorbed to particulate matter. Sorption to particulates immobilizes mercury and is dependent on the presence of organic matter, complexing agents (sulfides) and clay fractions. Bacterial metabolism and chemical reduction can mobilize sorbed mercury from particulate matter to more volatile forms. Ionic mercury (i.e., mercuric mercury) can be transformed to methylmercury (MeHg) by anaerobic, sulfur-reducing bacteria, which produce MeHg as a byproduct of their natural sulfur chemistry (Gilmour and Henry, 1991, Gilmour et al., 1992, and Zillioux et al., 1993). The major site of methylation in aquatic systems is the sediment, but methylation also occurs in the water column (Wright and Hamilton, 1992, Parks et al., 1989, and Gilmour and Henry, 1991). Once MeHg is produced, it can either be demethylated via biotic and abiotic mechanisms (Sellers et al., 1996) or enter into the food web. The rate of mercury methylation is influenced by a number of environmental factors that affect both the availability of mercuric ions for methylation and the growth of the methylating microbial populations:

- Bacterial methylation rates appear to increase under anaerobic conditions (oxygen-poor environments exhibit a reducing electrochemical potential that favors sulfur metabolism by sulfur-reducing bacteria).

- Sulfate stimulates formation of methylmercury (sulfate is used by sulfur-reducing bacteria in their metabolic process).

- Increasing water temperature enhances bacterial activity, thereby increasing the formation of methylmercury.

- The presence of organic matter can stimulate growth of microbial populations (and reduce oxygen levels), thereby increasing the formation of MeHg.

- Increasing hydrogen ion concentrations increase the formation of MeHg (Xun et al., 1987 and Winfrey and Rudd, 1990) by enhancing mercury uptake by bacteria (Kelly et al., 2003).

- Sulfide inhibits MeHg formation by binding with inorganic mercury ions and forming an insoluble mercury-sulfide complex, thereby limiting the bioavailability of inorganic mercury to sulfur-reducing bacteria.

MeHg is the most bioavailable and toxic form of mercury. Based on the relationship between MeHg production and total mercury concentration, the proportion of mercury as MeHg in sediment and associated organisms has been found to be proportional to the distance from the mercury source (Hill et al., 1996). In addition, organisms at lower trophic levels usually contain the lowest proportion of total mercury as MeHg (May et al., 1987 and Watras and Bloom, 1992), while organisms higher in the food chain (i.e., piscivorous fish, birds, mammals) contain a higher proportion of total mercury as MeHg (generally over 90 percent of the total mercury) (Huckabee et al., 1979, Watras and Bloom, 1992, Bloom, 1990, and Grieb et al., 1990). Several studies have been identified which investigated total mercury and MeHg concentrations in seagrass species. Seasonal variations in both total mercury and MeHg concentrations have been identified and concentrations are generally greater in the older plant material and in the root mat (Ferrat et al., 2002, Capiomont et al., 2000, and Pannhorst and Weber, 1999). Partitioning of MeHg as a function of total mercury does not appear to be a factor between above ground (shots, leaves, stems) and below ground (roots and rhizomes) portions of the plants (6.9% MeHg in above ground eelgrass tissue, 6.4% MeHg in below ground tissue [Pannhorst and Weber, 1999]).

A variety of adverse biological effects have been attributed to mercury. Enzymatic impacts have been noted in aquatic plants (Ferrat et al., 2002). Mercury is a known teratogen, mutagen, and carcinogen. The reproduction, growth, metabolism, blood chemistry, and oxygen exchange of marine and freshwater organisms is adversely affected by mercury. Mercury readily bioaccumulates and elimination from mammalian systems is slow (USEPA, 1999). Retention times appear to be longer for MeHg than for inorganic forms. Biological half-lives of 2 to 3 years in fish have been reported (USEPA, 1999).

Mercury in SWMU 1 surface soil and SWMU 2 surface and subsurface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in their order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 0.1 mg/kg: Toxicological benchmark for earthworms (Efroymson et al., 1997b)

- 0.3 mg/kg: Toxicological benchmark for terrestrial plants (Efroymson et al., 1997a)

Mercury in SWMU 1 surface soil has the potential to impact terrestrial avian omnivores via dietary (food web) exposures. Mercury in SWMU 2 surface soil also has the potential to impact terrestrial avian herbivores and omnivores, while mercury in SWMU 2 estuarine wetland sediment has the potential to impact aquatic avian invertebrate consumers via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of mercury ingestion by birds. A three-generation study with mallard ducks using methyl mercuric dicyandiamide indicated that a dose (oral in diet) of 0.064 mg/kg-BW/day had an adverse effect on egg and duckling production (Sample et al., 1996). This dose was considered a chronic LOAEL. A chronic NOAEL of 0.0064 mg/kg-BW/day was estimated by applying a safety factor of ten (10) to the chronic LOAEL value. A second study using Japanese quail (1-year reproductive study with mercuric chloride) indicated that a dose of 0.45 mg/kg-BW/day (oral in diet) had no effect on fertility and egg hatchability, while a dose of 0.9 mg/kg-BW/day had adverse effects on these reproductive indices (Sample et al., 1996). The 0.45 mg/kg-BW/day dose was considered a chronic NOAEL and the 0.9 mg/kg-BW/day dose was considered a chronic LOAEL. These two studies, one using inorganic mercury (mercuric chloride) and one using MeHg (methyl mercuric dicyandiamide) form the basis of the NOAEL and LOAEL values developed for avian dietary exposures to mercury in SWMUs 1 and 2 surface soil and SWMU 2 estuarine wetland sediment (see Section 4.4).

Finally, mercury in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of mercury ingestion by mammals. A 93-day study using mink indicated that a dose of 0.025 mg/kg-BW/day (administered orally as methyl mercury chloride) caused mortality, weight loss, and behavioral abnormalities (Sample et al., 1996). This dose was considered a chronic LOAEL. No adverse effects were observed at a dose of 0.015 mg/kg-BW/day; therefore, this dose was considered a chronic NOAEL. A second study using mink (6-month reproductive study with mercuric chloride) indicated that a dose of 1.0 mg/kg-BW/day (oral in diet) had no effect on fertility and kit survival (Sample et al., 1996). This dose was considered a chronic NOAEL. A chronic LOAEL of 10 mg/kg-BW/day was estimated by applying a factor of ten (10) to the chronic NOAEL value (Sample et al., 1996). These two studies, one using inorganic mercury (mercuric chloride) and one using MeHg (methyl mercury chloride) form the basis of the NOAEL and LOAEL values developed for West Indian manatee dietary exposures to mercury in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.7 Selenium

Selenium is a naturally occurring element commonly found in rocks and soil. Four stable valence states of selenium are found naturally, elemental (Se^{0}), selenides (Se^{2-}), alkali selenites (Se^{4+}), and selenates (Se^{6+}). Elemental selenium and selenides are insoluble, while the selenites and selenates are water soluble (ATSDR, 2003). Commercial and industrial uses include use as a nutritional supplement, in the glass industry, and as a component of paints, inks, rubber, pigments, pharmaceuticals, pesticides, and fungicides.

In the environment, selenium is not often found in the pure form. Important factors regulating the form of selenium include pH, redox potential, and the presence of metal oxides. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals (Irwin et al., 1998). Selenium will readily combine with these and other metals directly or in solution and reacts with oxygen to form stable selenium dioxide. Within surface waters, the salts of selenic and selenious acids are prevalent. Depending on the pH of the surface water body, selenium compounds can be highly soluble and do not adsorb to sedimentary particles. Within sediments, organic selenides and selenium oxide are the dominant forms found. Natural transport properties include weathering of rock material, volatilization by plants and animals, and volcanic activity. The principle release mechanism of selenium to the environment, however, is coal combustion. Though generally stable in soils, soluble selenium compounds in agricultural fields can be transported from the field in irrigation and drainage waters. Oxidation state, which is dependent upon pH, redox potential, and biological activity, is the principal factor governing the behavior of selenium in the environment. Bacterial and fungal action produces methylselenium (MeSe) and other volatile, organic selenium compounds. In sediments, especially in acidic, reducing, organic-rich environments, selenium forms strong metal selenides complexes which sorb to sediment particles and are relatively immobile and stable (Irwin et al., 1998). Selenium, like mercury, interacts readily with sulphur. Synergistic and antagonistic interactions with mercury have been noted for selenium (Irwin et al., 1998).

Inorganic selenites and selenates, which are more commonly found in alkaline and oxidizing environments, are more bioavailable as they are water soluble (Purkerson et al., 2003). They are readily taken up by plants and converted to various organic compounds (ATSDR, 2003). This uptake is regulated by soil type, pH, organic material, redox potential, and total selenium concentrations. Selenites have been shown to be more concentrated in algae and benthic invertebrates, while equal proportions of the two forms have been measured in fish (ATSDR, 2003). Selenium is identified as a weakly bioaccumulative chemical; accumulation and sensitivity, however, are independent on trophic levels as well as species and complex biogeochemical cycling (Purkerson et al., 2003). However, as selenium is also an essential nutrient, it is metabolized by animal species, prevents tissue damage from oxygen, and is readily eliminated (Maher et al., 2004). The relative toxicity of selenium compounds has been identified as hydrogen selenides ~ dietary selenomethionine > selenites ~ water selenomethionine > selenate > elemental selenium > metal selenides ~ methylated selenium compounds (Irwin et al., 1998). Chatterjee et al. (2001) investigated selenium concentrations in seagrass species in India. Seasonal variations were noted and total selenium concentrations were found to be greater in roots (0.21 micrograms per kilogram [ug/kg] dry weight) than in stems (0.17 ug/kg) and leaves (0.11 ug/kg).

As mentioned, selenium sensitivity is dependent upon species, life stage, nutritional status, and health of individual organisms (Irwin et al., 1998). Younger animals and those consuming low-protein diets appear to be impacted more. Very high amounts of selenium can result in reproductive and survivorship effects in invertebrates, birds, and mammals. Exposure to high levels of selenium compounds caused malformations in birds, but selenium has not been shown to cause birth defects in mammals (ATSDR, 2003). Reproductive impacts have been identified concurrently with no impact on adult survivorship in fish (Irwin et al., 1998). Seed germination and growth inhibition has been noted in plants, yet selenium-deficient soils have also been identified.

Based on the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a), selenium in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of selenium ingestion by mammals. A one-year study using rats studied the effects of potassium selenate on reproduction (Sample et al., 1996). A dose of 0.20 mg/kg-BW/day (oral in water) had no effect on various reproductive indices. This dose was considered to be a chronic NOAEL. A dose of 0.33 mg/kg-BW/day was identified as the chronic LOAEL based on a reduction in the number of second-generation young. This study forms the basis of the NOAEL and LOAEL values developed for West Indian manatee dietary exposures to selenium in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.8 Tin

Tin occurs naturally in the earth's crust and may be released to the environment from natural and anthropogenic sources. Inorganic tin may be released from smelting and refining processes, industrial uses of tin, waste incineration, and burning of fossil fuels (ATSDR, 2005c). In general, organotin compounds are released due to anthropogenic uses (antifouling paints, slimicides on masonry, disinfectants, and biocides for cooling systems, power station cooling towers, pulp and paper mills, breweries, leather processing, and textile mills), but can be produced in the environment by biomethylation of inorganic tin. Of the 260 known organotin compounds, all but a few are manufactured.

Inorganic tin may exist as either divalent (Sn^{2+}) or tetravalent (Sn^{4+}) cationic ions under environmental conditions and cannot be degraded in the environment. It may undergo oxidation-reduction, ligand exchange, and precipitation. In aquatic environments, inorganic tin can be transformed into organometallic forms by microbial methylation (Hallas et al., 1982). Methylation of tin in sediments is positively correlated with increasing organic content. Most commercially used organotin compounds are relatively immobile in environmental media due to their low vapor pressure, low water solubilities, and high affinities for soils and organic sediments (ATSDR, 2005c). Organotins are generally persistent in sediment and may be significantly bioconcentrated by aquatic organisms. There is general agreement that inorganic tin is not highly toxic.

Tin in SWMU 1 surface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are limited to a toxicological threshold for plants (50 mg/kg; Efroymson et al., 1997a).

3.2.1.9 Zinc

Zinc is an element commonly found in the Earth's crust. It is released to the environment from both natural and anthropogenic sources. The primary anthropogenic sources of zinc in the environment are related to mining and metallurgic operations involving zinc and use of commercial products containing zinc (ATSDR, 2005d).

Zinc occurs in the environment mainly in the +2 oxidation state (ATSDR, 2005d). Zinc sorbs strongly onto soil particles. Mobilization in soils depends on the water solubility of the speciated forms of the compound, as well as soil cation exchange capacity, pH, and redox potential. At pH values below 7, pH and solubility of zinc are inversely related (i.e., decreased pH results in increased solubility, and thus, increased potential for mobility). Low soil cation exchange capacity and oxidizing conditions also increase the mobility of zinc. As pH increases over 7, solubility decreases and zinc absorption to soil increases. Relatively little land-disposed zinc at waste sites is in the soluble form; therefore, mobility is limited by a slow rate of dissolution (ATSDR, 2005d). Consequently, movement toward groundwater is expected to be slow unless zinc is applied to soil in soluble form or accompanied by corrosive substances (i.e., mine tailings). Plants and animals may bioaccumulate zinc, but biomagnification in terrestrial food chains has not been observed (ATSDR, 2005d).

Zinc can occur in both suspended and dissolved forms in surface water. Dissolved zinc may occur as the free (hydrated) zinc ion or as dissolved complexes and compounds with varying degrees of stability. Water hardness, pH, and metal speciation are important factors in controlling the water column concentration of zinc. Zinc partitions to sediments or suspended solids in surface waters through sorption onto hydrous iron and manganese oxides, clay minerals, and organic material, resulting in the enrichment of zinc in suspended and bed sediments. The bioavailability of zinc in sediments appears to be controlled by the AVS concentration (Berry et al., 1996, and Sibley et al., 1996). Zinc is an essential micronutrient and uptake in most aquatic organisms appears to be independent of environmental concentrations (MacDonald, 1994). It has been found to bioaccumulate in some organisms, though there is no evidence of biomagnification (Jaagumagi, 1990).

Zinc in SWMU 1 surface soil and SWMU 2 surface and subsurface soil has the potential to impact terrestrial plants and invertebrates. Available literature-based toxicological benchmarks for terrestrial plants and invertebrates are listed below in order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 50 mg/kg: Toxicological threshold for terrestrial plants (Efroymson et al., 1997a)
- 200 mg/kg: Toxicological threshold for earthworms (Efroymson et al., 1997b)

Zinc in SWMU 2 estuarine wetland sediment also has the potential to impact aquatic invertebrates (i.e., benthic macroinvertebrates). Available literature-based toxicological benchmarks for aquatic invertebrates are listed below in order of increasing concentration. The lowest of the listed toxicological benchmarks was used in Step 2 of the screening-level ERA and Step 3b of the baseline ERA.

- 102 mg/kg: Freshwater LEL (Persaud et al., 1993)
- 121 mg/kg: Consensus-based freshwater TEC (MacDonald et al., 2000)
- 124 mg/kg: Marine TEL (MacDonald, 1994)
- 150 mg/kg: Marine and estuarine ER-L value (Long et al., 1995)
- 271 mg/kg: Marine PEL (MacDonald, 1994)
- 410 mg/kg: Marine and estuarine ER-M value (Long et al., 1995)
- 410 mg/kg: Marine AET (Buchman, 1999)
- 459 mg/kg: Consensus-based freshwater PEC (MacDonald et al., 2000)
- 820 mg/kg: Freshwater SEL (Persaud et al., 1993)

In addition to lower trophic level terrestrial and aquatic receptor groups, zinc in SWMU 1 surface soil has the potential to impact terrestrial avian omnivores and zinc in SWMU 2 surface and subsurface soil has the potential to impact terrestrial avian herbivores and omnivores via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of zinc ingestion by birds. A 44-week reproduction study conducted with white leghorn hens indicated that a dose of 14.5 mg/kg-BW/day (oral in diet) caused no effect on egg hatching success (Sample et al., 1996). This dose was considered a chronic NOAEL. Egg hatching success was impaired at a dose of 131 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for avian dietary exposures to zinc in SWMU 1 surface soil and SWMU 2 surface and subsurface soil (see Section 4.4).

Finally, the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a) indicated that zinc in SWMUs 1 and 2 open water sediment has the potential to impact the West Indian manatee via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of zinc ingestion by mammals. A 25-week reproductive study using mink indicated that an oral dose of 20.8 mg/kg-BW/day caused no impairment on reproductive indices (ATSDR, 1992b). This dose was considered a chronic NOAEL. A chronic LOAEL of 208 mg/kg-BW/day was estimated by applying a factor of ten (10) to the chronic NOAEL value. This study forms the basis of the NOAEL and LOAEL values developed for West Indian manatee dietary exposures to zinc in SWMUs 1 and 2 open water sediment (see Section 4.4).

3.2.1.10 4,4’-DDT, 4,4’-DDD, 4,4’-DDE

4,4’-DDT and its primary metabolites (4,4’-DDD and 4,4’-DDE) are manufactured chemicals and are not know to occur naturally in the environment (ATSDR, 2002). Historically, DDT was released to the environment during its production, formulation, and extensive use as a pesticide in agriculture, and vector control applications in aquatic environments. 4,4’-DDD also was used as a pesticide, but to a much lesser extent than 4,4’-DDT. 4,4’-DDT was banned for use in the United States after 1972.

4,4’-DDT and its metabolites are very persistent in the environment. When deposited on soil, 4,4’-DDT, 4,4’-DDD, and 4,4’-DDE are strongly absorbed. As a result of their strongly binding to soil, they mostly remain on the surface layers. As such, there is little leaching into the lower soil layers and groundwater. They may photodegrade on the soil surface or biodegrade. 4,4’-DDT biodegrades primarily to 4,4’-DDE under aerobic conditions and 4,4’-DDD under anaerobic conditions. The dominant fate processes in the aquatic environment are volatilization and adsorption to biota, suspended particulate matter, and sediment. 4,4’-DDT bioconcentrates in aquatic organisms and bioaccumulates in the food chain. Accumulation is significantly higher in the pelagic food web than in the benthic food web (ATSDR, 2002).

4,4’-DDT, 4,4’-DDD, and 4,4’-DDE in SWMU 1 surface soil and 4,4’-DDT and 4,4’-DDE in SWMU 1 subsurface soil have the potential to impact terrestrial plants and invertebrates. Toxicological benchmarks for terrestrial plants and invertebrates are absent from the literature. The Ministry of Housing, Spatial Planning and Environment (MHSPE, 2000) has developed a target and intervention value for total DDT/DDD/DDE for a standard soil consisting of 10 percent organic matter and 25 percent clay (0.01 mg/kg and 4 mg/kg, respectively). The mean of the target and intervention value (i.e., 400 mg/kg) was used as the soil screening value for 4,4’-DDD, 4,4’-DDE, and 4,4’-DDT in Step 2 of the screening-level ERA and Step 3a of the baseline ERA).

In addition to lower trophic level terrestrial receptor groups, 4,4’-DDT, 4,4’-DDD, and 4,4’-DDE in SWMU 1 surface soil have the potential to impact terrestrial avian omnivores via dietary (food web) exposures. A literature search, conducted as part of the screening-level ERA and Step 3a of the baseline ERA, identified studies that have investigated the toxicological effects of 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE ingestion by birds. A 2-year reproduction study conducted with American kestrels indicated that an oral dose of 0.05 mg/kg-BW/day 4,4'-DDE caused no effect on reproductive indices (McLane and Hall, 1972). This dose was considered a chronic NOAEL. Reproductive impairment was observed at a dose of 0.5 mg/kg-BW/day. This dose was considered a chronic LOAEL. This study forms the basis of the NOAEL and LOAEL values developed for terrestrial avian omnivore dietary exposures to 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE in SWMU 1 surface soil.

3.2.2 Transport and Exposure Pathways

A transport pathway describes the mechanisms whereby chemicals may be transported from a source of contamination to ecologically relevant media. An exposure pathway links a source of contamination with one or more receptors through exposure to one or more media. Exposure, and thus potential risk, can only occur if each of the following conditions is present (USEPA, 1998):

- A source of contamination must be present.
- Release and transport mechanisms must be available to move the contaminants from the source to an exposure point.
- An exposure point must exist where ecological receptors could contact the affected media.
- An exposure route must exist whereby the contaminant can be taken up by ecological receptors.

3.2.2.1 <u>Source Areas and Mechanisms of Transport</u>

The disposal areas at SWMUs 1 and 2 represent potential source areas for the release of chemicals to abiotic media (i.e., surface and subsurface soil). Contaminated surface and subsurface soil also represent potential source areas for the release of chemicals to groundwater and/or downgradient surface soil, surface water, and sediment.

The primary mechanisms for contaminant transport from potential source areas to downgradient abiotic media at SWMUs 1 and 2 are listed below. The list is limited to those transport pathways evaluated by the screening-level ERA and Step 3a of the baseline ERA and recommended for additional evaluation in Step 3b of the baseline ERA.

- Overland transport of chemicals with surface soil via surface runoff to downgradient surface soil (SWMU 1 and 2).
- Overland transport of chemicals with surface soil via surface runoff to downgradient estuarine wetland sediment (SWMU 2).
- Leaching of chemicals from surface soil and/or subsurface soil by infiltrating precipitation and transport to downgradient estuarine wetland sediment (SWMU 2) and Ensenada Honda sediment via groundwater (SWMUs 1 and 2).
- Uptake by biota from surface and/or subsurface soil and trophic transfer to upper trophic level receptors (SWMUs 1 and 2).

- Uptake by biota from estuarine wetland sediment and trophic transfer to upper trophic level receptors (SWMU 2).

- Uptake by biota from Ensenada Honda sediment and trophic transfer to upper trophic level receptors (SWMUs 1 and 2).

3.2.2.2 Exposure Points and Routes

Based upon the results of the Step 3a evaluation, key exposure pathways at SWMUs 1 and 2 include the following:

SWMU 1:

- Direct contact exposures by terrestrial plants and invertebrates to antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in surface soil and 4,4'-DDE and 4,4'-DDT in subsurface soil.

- Food web-based exposures by terrestrial avian herbivores to lead in surface soil.

- Food web-based exposures by terrestrial avian omnivores to cadmium, lead, mercury, zinc, 4,4'-DDD, 4.4'-DDE, and 4,4'-DDT in surface soil and 4,4'-DDE and 4,4'-DDT in subsurface soil.

- Food web-based exposures by amphibians and reptiles to cadmium, lead, mercury, zinc, 4,4'-DDD, 4.4'-DDE, and 4,4'-DDT in surface soil and lead, 4,4'-DDE and 4,4'-DDT in subsurface soil.

- Food web-based exposures by mammalian herbivores (i.e., West Indian manatee) to arsenic, cadmium, copper, mercury, selenium, and zinc in Ensenada Honda sediment.

SWMU 2**:**

- Direct contact exposures by terrestrial plants and invertebrates to antimony, copper, lead, mercury, and zinc in surface and subsurface soil.

- Food web-based exposures by avian herbivores to lead, mercury, and zinc in surface soil and copper, lead, and zinc in subsurface soil.

- Food web-based exposures by avian omnivores to lead, mercury, and zinc in surface soil and copper, lead, and zinc in subsurface soil.

- Food web-based exposures by amphibians and reptiles to lead, mercury, and zinc in surface soil and copper, lead and zinc in subsurface soil.

- Direct contact exposures by aquatic invertebrates (i.e., benthic invertebrates) to copper, lead, and zinc in estuarine wetland sediment.

- Food web-based exposures by aquatic avian invertebrate consumers to lead and mercury in estuarine wetland sediment.

- Food web-based exposures by mammalian herbivores (West Indian manatee) to arsenic, cadmium, copper, mercury, lead, selenium, and zinc in Ensenada Honda sediment.

An additional exposure pathway recommended in the screening-level ERA and Step 3b of the baseline ERA for additional evaluation in Step 3b of the baseline ERA at each SWMU involves exposures to aquatic upper trophic level reptilian receptors (sea turtles) to chemicals in Ensenada Honda sediment. Based on the paucity of data concerning the toxicological effects of chemicals for reptiles, a quantitative evaluation of the potential for risk to these species could not be performed in Steps 2 and 3a of the ERA process. Given the Federal status of sea turtles in Puerto Rico, a review of the available literature and additional evaluation was recommended for Step 3b of the baseline ERA. This evaluation, presented below, includes an examination of their life history information and a summary of available sea turtle habitat within the open water portions of SWMUs 1 and 2 to determine whether potential exposure points and routes exist whereby sediment-associated contaminants may be encountered and subsequently taken up by aquatic reptiles. A thorough review of the scientific literature yielded no published studies that related food web exposures to toxicity in reptiles (i.e., no ingestion-based NOAELs were identified).

3.2.2.2.1 Sea Turtle Life History

Four sea turtle species potentially inhabit or seasonally visit the coastal waters adjacent to NAPR: green sea turtle, hawksbill sea turtle, leatherback sea turtle, and loggerhead sea turtle (Geo-Marine, Inc., 2005). The green and loggerhead sea turtles are listed as federally threatened species in Puerto Rico, while the hawksbill and leatherback sea turtles are listed as federally endangered species (USFWS, 2006a). Each species is protected under the 1973 Endangered Species Act (16 United States Code [USC] 1531-1544). Except during the female's nesting activities, sea turtles spend their lives at sea. Males almost never return to the land following hatching.

Three distinct life history stages are recognized for most sea turtles: 1) the hatchling phase, characterized by the early life-stage open ocean, pelagic lifestyle, when small turtles primarily float with the currents and major oceanic gyres, often congregating in *Sargassum* weed and convergence zones where food is plentiful; 2) the juvenile and/or subadult phase, when sexually immature turtles recruit back into shallow coastal areas to feed and develop; and 3) the adult phase, when reproductively active individuals migrate from feeding areas to mating and/or nesting areas, typically every few years. Due to their pelagic nature, little is known about the time turtles spend in each phase and estimates vary widely. The data available indicate that growth rates and reproductive maturity are dependent on environmental factors, including temperature and food availability. Sea turtle migration distances are impressive; some species have a circumglobal distribution and are encountered from the northern Atlantic and Canadian waters down to the southern tip of Africa. With the exception of the loggerhead, which often nests in the temperate zone, sea turtles generally nest on open subtropical beaches with neighboring deep water habitats, such as those present on NAPR. For many turtles, the nesting areas are often located on the female's natal beach and may be revisited year after year. Dietary preferences and trophic level status also vary by species, though with the exception of adult greens, sea turtles are generally carnivorous. Godley et al. (1988) investigated trophic status of European Atlantic and Mediterranean sea turtles using stable isotopes and found the following relationship: green < leatherback < loggerhead, with the loggerhead diet exhibiting the highest trophic level, on average 2 to 3 levels above greens. The following paragraphs present a summary of the life history and feeding ecology of each of the four species with the potential to inhabit the coastal regions surrounding NAPR.

Green Sea Turtle

Green sea turtles are named not for the color of their shells, but for the color of their body fat, which is thought to be due to their mainly herbivorous diet as adults. As hatchlings, the diet of the green sea turtle is the same as it is for other turtles. Hatchling greens feed on the marine plants, mollusks, crustaceans, and jellyfish available in the open water convergence zones until they reach somewhere between 8 and 30 centimeters (cm) standard carapace length (SCL) (NatureServe, 2006 and Moreale and Standora, 1998), between 1 and 3 years (Barmes et al., 1993). As juveniles, greens reside in inshore locations, but travel widely (Barmes et al., 1993). During this developmental period their eating habits shift to the adult diet, which is unique among sea turtles and is selectively focused on seagrasses and to a lesser extent macroalgae. One study presented gut content analysis data of 78.9% turtle grass, 9.7% other grasses, 8.2% algae, 1.8% substrate, and 1.4% animal matter, including sponges, tunicates, soft corals, hydroids, gastropod eggs, and hydrozoans, which were thought to be incidental takes during grazing (Mortimer, 1981). A stable isotope investigation agrees with this general dietary preference, which is not exclusively herbivorous (Godley et al., 1988). A review by Coyne (1994) demonstrated the high selectivity of this species, as the plant species with the highest concentrations in green sea turtle guts were often the rarest in the available foraging habitat. Mortimer

(1981) and Coyne (1994) both identified red algae as an important dietary item for migrating individuals and noted that major dietary differences have been noted between colonies within a few kilometers (km) of each other.

Green turtles travel daily, often over several miles, from shallow, low-energy feeding pastures to more protective reefs, coral shoals, and hard structures to rest at night (Diez et al., 2003a and Mortimer, 1981). Unless migrating, green turtle juveniles and adults mainly inhabit shallow waters within the tropical and subtropical regions (USFWS, 2006b and NatureServe, 2006), though juveniles are also commonly encountered in more temperate waters (NatureServe, 2006). They are present within the Caribbean region year-round (Barmes et al., 1993) and critical habitat associated with adult and juvenile feeding grounds has been identified for them in the waters surrounding Culebra Island and the Culebra Archipelago, Puerto Rico (50 Code of Federal Regulations [CFR] 226.208 and USFWS, 2006b). Adults and juveniles generally inhabit the same areas, but may segregate within a habitat by age and size (Seminoff et al., 2002 and Coyne, 1994). The home range of the green sea turtle, the area used during their normal, non-migratory daily activities, is assumed to be dependent on the suitability of available habitat and preferred diet. Estimates include 48 to 506 hectares in Florida and 22 to 311 hectares in the Gulf of Mexico for juveniles and 584 to 3,908 hectares in the Caribbean for adults (Godley et al., 2003 and Seminoff et al., 2002). Home ranges estimates indicate a generally smaller home range than that identified for the loggerhead but a larger home range than the hawksbill.

The age of sexual maturity of this species is not well documented, especially for males, but is likely linked to the availability of suitable habitat and diet. Estimates identified in the literature include 19 to 27 years (Godley et al., 1988) and 18 to 36 years (Barmes et al., 1993) in general to 18 to 26 years for populations in Texas and 27 to 33 years for populations in the U.S. Virgin Islands (Coyne, 1994). Age at maturity generally corresponds to a carapace length of approximately 60 to 88 cm SCL (Coyne, 1994). Once mature, adults do not reproduce every year. Mating periodicity is on the order of every two to three years. Males and females will migrate from widely spaced foraging grounds to more centralized subtropical and tropical mating and nesting areas. Migrations from feeding to nesting grounds up to 3,000 kilometers have been reported (NatureServe, 2006, Avens and Lohmann, 2004, and Seminoff et al., 2002). Nesting generally takes place on small, isolated, high energy beaches with deep sand and flanking hard structures, such as coral or rock (NatureServe, 2006, and Barmes et al., 1993). Females will nest several times over a season, resting in neighboring foraging areas in between and then will migrate back to foraging grounds at the end of the season. Due to the difficulty finding and then tagging males, their migration patterns are less studied and the periodicity of their movement is not reported in the literature.

Hawksbill Sea Turtle

Hawksbill sea turtles are named for the shape of their hooked jaw and narrow head which allows them to feed as adults in the crevices characteristic of reef and hard bottom habitats. Hatchling hawksbills live an epipelagic lifestyle characteristic of all sea turtles, and omnivorously feed in the open water convergence zones until approximately 20-30 cm SCL (MarineBio, 2006 and Diez and van Dam, 2002), for an unknown length of time. Following the hatchling phase, juvenile hawksbills recruit to shallow (less than 65 feet deep) inshore coral reefs, hard bottoms, rocky areas and occasionally seagrass habitats in subtropical and tropical waters (USFWS, 2006b, Diez et al., 2003b, and León and Bjorndal, 2002). Juvenile and adult hawksbills are generally carnivorous, feeding primarily on the sponges, jellyfish, squid, crabs, sea urchins, shellfish, and even fish (NatureServe, 2006) that are associated with reef habitat. Selective feeding, however, on rare sponges and anemone species by hawksbills even when other forage is available has been documented and their local abundance is generally well correlated with reef distribution (Troëng et al., 2005 and León and Bjorndal, 2002). Juvenile occurrence in seagrass meadows seems to require a lagoon habitat or nearby reef breaker and is thought to be associated with the presence of chicken liver sponges (*Chondrilla nucula)* (Diez et al., 2003b). This generalist diet places them on a higher trophic level than green turtles, likely on the same level as the loggerhead.

Hawksbill turtles have traditionally been identified as a relatively non-migratory species, when compared to other sea turtles that travel great distances during foraging and mating/nesting activities. Recent studies, however, have replaced this opinion. Though juveniles exhibit long-term residency in developmental habitats (Meylan, 1999a), and the species as a whole is considered subtropical to tropical in general (Troëng et al., 2005 and Diez and van Dam, 2002) individuals are encountered as far north as Massachusetts (MarineBio, 2006). Home range estimates are better defined for the hawksbill than for other sea turtles, though should be considered a lower limit based on the emerging evidence that they are more migratory. Home ranges (expressed as minimum distance traveled) of 110 to 1,936 km for adults and 46 to 900 km for juveniles were reported by Meylan (1999a) in the Caribbean region. Other estimates of home range include 7 to 21 hectares at Mona Island, Puerto Rico (van Dam and Diez, 1998) and 196 to 4,950 hectares in the West Indies (Horrocks et al., 2001). Like the green, hawksbills are present within the Caribbean region year-round (Barmes et al., 1993) and critical habitat has been identified for them in the beaches and surrounding waters of Culebra Island, Mona Island, Cayo Norte, and Culebrita Island, Puerto Rico for nesting (50 CFR 17.95 and USFWS, 2006) and the waters surrounding Mona and Monito Islands for juvenile and adult foraging grounds (50 CFR 226.209 and USFWS, 2006b).

Growth rates of hawksbills are strongly linked to prey abundance and water temperature, and vary geographically (Diez and van Dam, 2002). Estimates of the age of sexual maturity include 20 to 30 years (Barmes et al., 1993) and 15 years on a good diet (Diez and van Dam, 2002). Age at maturity has been reported at a carapace length of 58 cm SCL on the lower limit, but averages 83 to 85 cm SCL in the Caribbean (Diez and van Dam, 2002). Like the green, hawksbills mate every two to three years. Preferred nesting sites are located on undisturbed deep sand beaches, in both low and high energy environments (NatureServe, 2006). Unique to the species, female hawksbills have been known to crawl over fringing rocks and reefs to nest (USFWS, 2006b) and often prefer beaches with flanking hard structures (Barmes et al., 1993). Mona Island, Puerto Rico is an important nesting ground for Caribbean populations of hawksbills (NatureServe, 2006) and nest surveys have indicated one of the few areas in the Atlantic with increasing trends of nest numbers over time in recent years (Meylan, 1999b). Reproductively active males and females do not necessarily nest in areas close to their feeding grounds. Tagging studies indicate that migrating adults will cross paths with others between foraging and mating grounds (Meylan, 1999a), and that only 20% of the nesting females surveyed in Puerto Rico are from local waters (Troëng et al., 2005). Migration range estimates have noted post-nesting female movements of 200 to 435 km within 7 to 18 days (NatureServe, 2006). Female hawksbills nest several times within a season, foraging within 30 miles of the beach in the internesting period (approximately 17 days; Troëng et al., 2005). Males at Mona Island, Puerto Rico, have been observed using the reef areas up to 2 months to intercept females during the breeding season. Following the breeding season, males will move offshore to deeper waters within 100 km of Mona Island.

Leatherback Sea Turtle

The leatherback is the largest of the sea turtles and is named in credit of its distinctive, dark ridged, leathery shell. Virtually nothing is known about the hatchling phase of the leatherback lifestyle. Based on what is known about other turtles and the generally pelagic lifestyle of the leatherback, it is assumed that they spend the early years of their life like other sea turtles, generally moving with the currents and feeding on floating prey. Unlike other sea turtles, which shift to a benthic lifestyle following the pelagic hatchling phase, leatherbacks largely remain open ocean creatures throughout their lives. Their diet is focused on soft organisms that they can shred with their delicate jaws; jellyfish are their preferred food (James, 2001). Other soft-bodied prey, characteristic of oceanic convergence zone habitats and routinely identified in leatherback guts, include siphonophores, tunicates, seaweed, squid, and small crustaceans and fish (MarineBio, 2006, USFWS, 2006b, and James, 2001). A stable isotope investigation indicating a depleted carbon signature agrees with their pelagic lifestyle (Godley et al., 1988).

Due to their pelagic nature, leatherbacks are the most migratory and wide-ranging of all the sea turtles (USFWS, 2006b). They rarely approach land, and are typically encountered along oceanic frontal systems and vertical gradients in water temperature, salinity, and/or water color where food is abundant (James, 2001). When working a coastal area, they can be found in shelf waters deeper than 20 to 40 meters (m) deep (NatureServe, 2006). They have been tracked diving to depths of 1,000 m and demonstrate a circumglobal distribution from Alaska to the southern tip of Africa (MarineBio, 2006). Individual males have been tracked traveling over 4,500 miles and 40 degrees of latitude within 5 months (Lutcavage et al., 2003 and James, 2001). Leatherbacks have the largest known geographical range of any reptile and are the only known reptile that can remain active in temperatures below 40 degrees Fahrenheit (James, 2001). They accomplish this via thermoregulatory abilities that are unique among reptiles. A review of world data on their distribution indicates that leatherbacks less than 100 cm SCL are restricted to subtropical and warmer waters less than 26 degrees latitude, indicating that their thermoregulatory behaviors are growth dependent (Eckert, 2002 and James, 2001). The spatial presence of both juveniles and adults in northern waters is dependent on temperature and the availability of food, and has been directly correlated with the relative abundance of jellyfish in an area (James and Herman, 2001). Adult leatherbacks are only seasonally present within the Caribbean region during nesting season (Barmes et al., 1993). Based on their pelagic lifestyle and wide-ranging geographical extent, no estimates on home range are available in the literature or would be meaningful in relation to foraging habitat.

The available data indicates that leatherbacks mature faster than other sea turtles and have a shorter life expectancy (18 years; James, 2001). Estimates of the age at sexual maturity include 5 to 6 years (noted as more likely 13 to 14 years; James, 2001), 6 to 10 years (MarineBio, 2006), 8 to 15 years (Ocean Biogeographic Information System [OBIS], 2006), and 9 to 14 years (Godley et al., 1988). Once mature, adults reproduce every two to three years (OBIS, 2006). Reproductively active adults migrate thousands of kilometers between their foraging grounds and nesting beaches; there are accounts of females tagged in Nova Scotia found nesting in Suriname and Costa Rica (NatureServe, 2006). Known nesting populations are small, estimated at 35 females/year in Florida, 50 to 100 females/year in the US Virgin Islands, and 30 to 90 females/year in Puerto Rico (OBIS, 2006 and Barmes et al., 1993) and are found as far north as the coast of the Carolinas. Unlike other sea turtles, female leatherbacks do not necessarily return to their natal beaches to nest and may nest on multiple island beaches within a region and nesting season (NatureServe, 2006). Females generally prefer open access, sloped beaches backed by vegetation that are near deep water and/or rough seas (James, 2001 and Barmes et al., 1993). Unlike other turtles, flanking hard structures such as reefs or rock are not preferred by leatherback females (NatureServe, 2006 and James, 2001). Females will nest approximately 6 times over a season, and will rest from 8 to 12 days between nesting periods in offshore waters (James, 2001). Following the nesting season, Caribbean nesters move immediately to northern waters along the temperate Atlantic coast. Like the green, the migration patterns between foraging and mating habitats for male leatherbacks remains to be studied. It has been suggested that mating takes place in temperate waters and that the males do not migrate to the subtropics for breeding purposes (James, 2001).

Loggerhead

Loggerhead turtles are named for their thick, large heads supporting their powerful jaws which sustain their carnivorous lifestyle. Hatchling leatherbacks exhibit the characteristic epipelagic lifestyle, omnivorously feeding in open waters convergence zones until approximately 40-50 cm SCL (Moreale and Standora, 1998). Estimates of the length of the hatchling phase vary, from 2 to 5 years (NatureServe, 2006 and Moreale and Standora, 1998) to 7 to 12 years (USFWS, 2006b and Avens and Lohmann, 2004). Juvenile loggerheads recruit to coastal waters and take up the adult, benthic lifestyle, feeding on mollusks, crustaceans, fish, sponges, echinoderms, horseshoe crabs, and slow-moving or dead fish in both rocky and sedimentary habitats (USFWS, 2006b, Godley et al., 1998, and Godley et al., 1997). Loggerheads, especially juveniles, will also forage on jellyfish and other small prey concentrated on the water surface in convergence zones. Godley et al. (1988) noted that stable isotope analysis confirmed the high trophic status of the loggerhead.

Loggerheads are found in waters mainly associated with large sounds, bays, and estuaries and can be found hundreds of miles out to sea over the coastal shelf (Avens and Lohmann, 2004). Though not known to thermoregulate like the leatherback, they have a circumglobal range and can be found seasonally in Canadian waters (Godley et al., 1997). They often frequent offshore reefs, rocky places, and ship wrecks (USFWS, 2006b). Like the leatherbacks, loggerheads forage in more temperate areas and are seasonally present within the Caribbean region, mainly during nesting season (Barmes et al., 1993). Home ranges of 95,400 to 2,833,300 hectares have been calculated for loggerhead populations studied in the Gulf of Mexico (Renaud and Carpenter, 1994), reflecting their highly mobile lifestyle.

Loggerheads reach sexual maturity around 12 to 30 years (Barmes et al., 1993) and have a life expectancy of 30 to 50 years (MarineBio, 2006). Like other sea turtles, adults reproduce every two to three years (MarineBio, 2006). In general, loggerheads are more associated with the temperate and subtropical zones rather than the tropics. This is reflected in their preferred nesting habitat, primarily the southern coast of the U.S., from North Carolina to Florida (MarineBio, 2006). Nesting in tropical latitudes is rare (Barmes et al., 1993). Like the green and leatherback, loggerheads actively migrate long distances between their foraging grounds and nesting beaches. Females generally prefer high energy, steeply sloped beaches with gradual offshore approaches (NatureServe, 2006) and will nest approximately 2 to 5 times over a season (MarineBio, 2006). Information associated with the breeding migration patterns of male loggerheads was not identified in the literature.

3.2.2.2.2 *Potential Habitat*

Aerial surveys of turtles were performed from March 1984 through March 1996 along the Puerto Rican Coast. This information was summarized by Geo-Marine, Inc. (2005) in the NAPR Disposal Environmental Assessment (EA). Figures 3-8 and 3-9 (reproduced from Geo-Marine, Inc., 2005) present cumulative sea turtle sightings and potential turtle nesting sites on NAPR. Significant turtle observations were made near the mouth of the Ensenada Honda, the northern shore of Pineros Island, Pelican Bay, and the Medio Mundo Passage with the frequency of turtle observations listed as green > hawksbill > loggerhead > leatherback.

Based on the life history information presented above, as well as the description of aquatic habitats presented in Section 2.2.2, potential green sea turtle foraging habitat is located within the open water portions of each SWMU (turtle grass climax meadows with a high abundance of calcareous green algae). No coral reefs/hard bottom communities, preferred feeding habitat for hawksbills and loggerheads, have been identified within the open water portions of SWMUs 1 and 2. The closest patch reef habitat can be found near the mouth of the Ensenada Honda (approximately 1 mile from the open water portion of SWMU 1), while more extensive reef habitats are found along the north shore of Isla Pineros and Cabeza de Perro (Geo-Marine, Inc, 2005).

Several stretches of beach at NAPR have been identified as suitable nesting habitat for sea turtles. Beach nesting surveys performed by the Navy indicate that 73 and 16 nests were observed on 12 and 7

NAPR beaches in 2002 and 2004, respectively (Geo-Marine Inc., 2005). The majority of these nests were created by hawksbill females and were observed at or near the mouth of the Ensenada Honda. As indicated on Figure 3-8, turtles have not been sighted within the open water portions of SWMUs 1 and 2. Potential nesting habitat (i.e., sandy beaches) also has not been identified along the Ensenada Honda shoreline within each SWMU (the Ensenada Honda shoreline at SWMUs 1 and 2 is bordered by a red mangrove community exhibiting an extensive prop root system).

3.2.2.2.3 *Potential for Exposure*

As described in Section 3.1.3, exposure and thus potential for risk, can only occur if exposure points and routes exist where ecological receptors could contact affected media and whereby the contaminant can be taken up by ecological receptors. The primary mechanism for contaminant transport from potential source areas at SWMUs 1 and 2 to aquatic upper trophic level receptors is uptake by prey and/or forage biota from sediment and subsequent trophic transfer via dietary exposures.

Based on the life history information for each turtle species discussed above, potentially complete exposure pathways are present within the open water portions of SWMUs 1 and 2 for green sea turtles, via dietary exposures, but are likely incomplete for hawksbill, loggerhead, and leatherback turtles. Exposure points are present within the habitat offered for the green sea turtle based on the absolute presence of available forage material (in the form of seagrass). No exposure point is identified for hawksbill, loggerhead, and leatherback sea turtles based on their very selective feeding strategies and habitat preferences. The preferred feeding habitat of hawksbills and loggerheads (coral reefs/hard bottom communities) and associated prey species are lacking within the open water portion of each SWMU, while leatherbacks rarely approach land outside of the nesting season and forage within open deep water environments for soft-bodied organisms, mainly jellyfish.

Assessment of the potential for exposure can be performed via an examination of an Area Use Factor (AUF), a variable within the dietary intake calculation used to evaluate exposures for upper trophic level receptor species (see Section 4.4). An AUF of 1.0 assumes that a receptor spends 100 percent of its time on-site, an assumption that is valid for sessile or relatively immobile species, but is clearly not representative of sea turtles, which are highly mobile and migratory. The minimum (most conservative) home ranges identified from the literature in the Caribbean region for green sea turtles are 22 to 311 hectares in the Gulf of California for juveniles and 584 to 3,908 hectares in the Caribbean for adults (Seminoff et al., 2002). These home ranges correspond to AUFs of 0.025 to 0.35 for juvenile green turtles and 0.0019 to 0.013 for adult green sea turtles at SWMU 1 (based on an area of 7.62 hectares for the open water portion of SWMU 1) and AUFs of 0.01 to 0.15 for juvenile green sea turtles and 0.0008 to 0.006 for adult green sea turtles at SWMU 2 (based on an area of 3.21 hectares for the open water portion of SWMU 2). Given the close proximity of SWMUs 1 and 2, AUF values also can be derived using the combined open water area of each SWMU (10.83 hectares). AUFs under this scenario range from 0.03 to 0.49 for juvenile sea green turtles and 0.003 to 0.02 for adult green sea turtles.

The range of AUFs derived for adult green sea turtles indicates that, at most, any individual adult may obtain a maximum of two percent of its forage material from the open water portions of the Ensenada Honda downgradient from SWMUs 1 and 2. The AUF calculations (and thus the indication of potential for exposure) would be even lower if they were based on populations (vs. individuals) of turtles (where the integrated home range would be even larger) and/or more realistic assumptions (mean rather than minimum home ranges, factors considering the quality of each forage component available, seasonal considerations, etc.). Although this exposure assessment indicates that a complete exposure pathway is potentially present, it is concluded that there is a minimal and insignificant potential for exposure of adult green sea turtles to chemicals detected in Ensenada Honda sediments downgradient from SWMUs 1 and 2.

Juvenile green sea turtles show the greatest potential for exposure (minimum AUF of 0.03 and maximum AUF of 0.49 based on the combined open water area of SWMUs 1 and 2). This AUF indicates that any individual juvenile green sea turtle may obtain a maximum of 49 percent of its forage material from the open water portions of SWMUs 1 and 2. While use of the minimum home range in AUF calculations indicates that the potential for exposure for an individual juvenile green sea turtle is high, other factors, when considered, temper this estimation. Coral reefs provide green sea turtles with shelter during interforaging periods and serve as refuge from predators (50 CFR 226.208). Green sea turtle home ranges show considerable overlap between food and shelter sites (Makowski et al., 2005). As evidenced by Figure 2-3, coral reef and hard bottom communities are absent from the open water portions of SWMUs 1 and 2. The absence of these features indicates that the Ensenada Honda does not provide favorable developmental habitat for juvenile green sea turtles. The importance of both seagrass and coral reef habitat for juvenile green sea turtles is illustrated by the classification of the waters surrounding Culebra Island as critical habitat (50 CFR 226.208). This area includes extensive sea grass and coal reef habitat supporting both juvenile and subadult green turtle populations. Information of green sea turtle sightings at NAPR also illustrates the importance of both seagrass and reef habitat. Sea turtle sightings have primarily been restricted to offshore locations where both seagrass and coral reef habitat is present (see Section 3.2.2.2.2 and Figure 3.8). While a complete exposure pathway is potentially present for juvenile green sea turtles within the open water portion of SWMUs 1 and 2 (based on the absolute presence of forage material), it is concluded that the potential for exposure is minimal based on the absence of favorable developmental habitat.

In summary, it is concluded that there is minimal potential for exposure of sea turtles to chemicals detected in Ensenada Honda sediment downgradient from SWMUs 1 and 2. As such, no further evaluation of sea turtles is recommended for the open water portions of SWMUs 1 and 2.

3.3 Assessment Endpoints and Risk Questions

Assessment endpoints are intended to focus the risk assessment on particular components of the ecosystem that could be adversely affected by chemicals. The assessment endpoints selected for the baseline ERA at SWMUs 1 and 2 are listed below:

Terrestrial habitat (SWMUs 1 and 2):

- *Survival growth and reproduction of terrestrial invertebrate communities* – Soil invertebrates promote soil fertility by breaking down organic matter and releasing nutrients. They also improve aeration, drainage, and aggregation of soils, and serve as a forage base for many terrestrial species. The soils at each SWMU will support fewer terrestrial avian invertebrate consumers if chemical concentrations in soils are limiting the survival, growth, and reproduction of soil invertebrates

- *Survival, growth, and reproduction of avian terrestrial omnivore populations* – Avian omnivores are susceptible to bioaccumulative chemicals, especially those that may have the potential to biomagnify through terrestrial food webs. The community also serves as a means of population control for its prey items and as a prey base for terrestrial avian carnivores.

<u>Estuarine wetland system (SWMU 2)</u>:

- *Survival, growth, and reproduction of benthic invertebrate communities (SWMU 2)* – Benthic invertebrates serve as the prey base for many aquatic and semi-aquatic species. Many also are detritivores, playing an important role in the breakdown of organic matter and release of nutrients. The estuarine wetland system will support fewer fish and birds if SWMU-related chemical concentrations are limiting the survival, growth, or reproduction of the benthic macroinvertebrate community.

- *Survival, growth, and reproduction of aquatic avian invertebrate consumer populations* – These receptors are top-level consumers within the estuarine wetland system at SWMU 2 and are susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify through aquatic food webs. The community also serves as a means of population control for its prey items.

<u>Open Water Habitat (SWMUs 1 and 2)</u>:

- *Survival, growth, and reproduction of West Indian manatee populations* – West Indian manatees are susceptible to chemicals that may bioaccumulate within their diet of submerged aquatic vegetation. Food web impacts beyond the manatees are not of concern as manatees have no known predators due to a size refuge. Manatees were selected as an assessment endpoint for the open water portions of SWMUs 1 and 2 based on their known occurrence within the Ensenada Honda and the Federal status of this species in Puerto Rico (endangered).

Assessment endpoints were not selected for terrestrial amphibians and reptiles. As discussed in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a), there is a paucity of data concerning the toxicological effects of chemicals for amphibians and reptiles, rendering a quantitative evaluation problematic. For the baseline ERA, it will be assumed that any amphibians and reptiles at SWMUs 1 and 2 are not exposed to significantly higher concentrations of potential ecological risk drivers than the other upper trophic level receptor species selected as assessment endpoints for the baseline ERA. Therefore, a conclusion of acceptable or unacceptable risk to the upper trophic level terrestrial receptors evaluated in the baseline ERA at a given SWMU also also will apply to terrestrial amphibians and reptiles.

Although antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were identified as potential ecological risk drivers for terrestrial plant communities at SWMU 1 and antimony, copper, lead, mercury, and zinc were identified as potential ecological risk drivers for terrestrial plant communities at SWMU 2, an assessment endpoint was not selected for terrestrial plants. During the habitat characterization conducted at SWMUs 1 and 2 (Geo-Marine Inc., 2000; see Appendix C), the field biologists made visual observations to characterize the health of the terrestrial plant communities at each SWMU. Indications of an altered plant community used in the assessment included the presence of chlorotic leaves (pale foliage due to reduced chlorophyll content) and epinasty (deformities of leaves and stems), patches of altered plant growth, absence of plants (bare ground), and changes in species composition. To determine the presence of an altered plant community, nearby representative sites were selected as controls. The controls were chosen in order to be representative of the plant communities present at SWMUs 1 and 2 (upland coastal scrub and/or forest communities). Field observations concluded that the terrestrial plant communities at each SWMU are growing healthy and vigorously, with no evidence of stress. Furthermore, there were no noticeable differences in plant community species composition between the controls and each SWMU. The habitat characterization did note that SWMU 1 had more grassy areas within the coastal scrub forest community than the corresponding control, but concluded that this was probably the result of past soil disturbances (e.g., presence of an un-maintained road for access to several monitoring wells). Though all potential impacts on the upland vegetative communities cannot be quantified by visual inspections alone, potential risk to terrestrial plants are considered acceptable based on observations made during the habitat characterization. Therefore, terrestrial plants are excluded from further consideration in the baseline ERA for SWMUs 1 and 2.

An assessment endpoint also was not selected for avian herbivore food-web exposures. Lead in surface soil was identified as a potential ecological risk driver for both terrestrial avian omnivore and herbivore food web exposures at SWMU 1. Lead, mercury, and zinc in surface soil and copper, lead, and zinc in subsurface soil also were identified as potential ecological risk drivers for both terrestrial avian omnivore and herbivore food web exposures at SWMU 2. Based on the refined Step 3a risk calculation (Baker, 2006a), avian omnivores represent the more exposed feeding guild and are at greater risk to these potential ecological risk drivers. Therefore, the baseline ERA will focus on avian omnivores. Given that avian omnivores represent the feeding guild that is potentially at greatest risk from food web-based exposures to chemicals in SWMUs 1 and 2 surface and/or subsurface soil, a conclusion of acceptable risk to avian omnivores at a given SWMU also would apply to avian herbivores. Even if the baseline ERA concludes that risks to avian omnivores are not acceptable for a given SWMU-chemical-medium combination, the resultant PRG derived for the protection of avian omnivores also would be protective of avian herbivores.

Risk questions ask how the assessment endpoints could be affected by site-related conditions. Risk questions also clarify and articulate relationships that are possible through consideration of available data, information from the scientific literature, and the best professional judgment of risk assessors. Finally, they can form the basis for developing a study design for subsequent steps of the ERA process. The risk questions associated with the assessment endpoints identified above are listed below.

- Are the concentrations of chemicals identified as potential ecological risk drivers in SWMUs 1 and 2 surface and/or subsurface soil high enough to impair the survival, growth, and reproduction of terrestrial invertebrate communities?

- Are the concentrations of chemicals identified as potential ecological risk drivers in SWMUs 1 and 2 surface and/or subsurface soil high enough to impair the survival, growth, and reproduction of terrestrial avian omnivore populations?

- Are the concentrations of chemicals identified as potential ecological risk drivers in SWMU 2 estuarine wetland sediment high enough to impair the survival, growth, and reproduction of aquatic invertebrate communities?

- Are the concentrations of chemicals identified as potential ecological risk drivers in SWMU 2 estuarine wetland sediment high enough to impair the survival, growth, and reproduction of aquatic avian invertebrate consumer populations?

- Are the concentrations of chemicals identified as potential ecological risk drivers in SWMUs 1 and 2 open water sediment high enough to adversely effect the survival, growth, or reproduction of West Indian manatee populations?

4.0 STUDY DESIGN/DATA QUALITY OBJECTIVES

Step 4 of the ERA process (Study Design/Data Quality Objectives) establishes the measurement endpoints, the study design, data quality objectives, and data analysis methods for the additional site investigations necessary to complete the ecological risk assessment (USEPA, 1997). The proposed components of the Step 4 investigations will provide multiple lines of evidence on which to evaluate potential ecological risks or existing ecological impacts from exposures to contaminants in surface soil, subsurface soil, estuarine wetland sediment, and open water sediments at SWMUs 1 and/or 2. These lines of evidence are site-specific, direct measures of potential ecological effects and are thus preferable to the comparison of chemical concentrations to conservative, non-site-specific screening values, and other conservative assumptions, which form the basis for screening-level ERAs. The use of multiple lines of evidence reduces the dependence on any one type of data and thus reduces the uncertainty of the analysis, allowing for more confident decisions to be made about the need for, and extent of, remedial actions.

4.1 Measurement Endpoints

The conceptual model for SWMUs 1 and 2, begun in Step 3b (see Section 3.0), is completed in Step 4 with the development of measurement endpoints. Measurement endpoints are measures of biological effects (e.g., laboratory toxicity test results) that are related to each respective assessment endpoint (USEPA, 1997). The proposed measurement endpoints selected for each assessment endpoint identified in Section 3.3 are identified in the Sections that follow:

4.1.1 SWMU 1 Measurement Endpoints

The proposed measurement endpoints for the baseline ERA at SWMU 1 are as follows:

Survival, growth, and reproduction of terrestrial invertebrate communities:

- Comparison of antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4,-DDE, and 4,4'-DDT concentrations in soil with invertebrate-based soil screening values and literature-based effect levels.

- Comparison of results of 28-day laboratory toxicity tests (survival, growth, and reproduction) with the earthworm *Eisenia fetida*, using site and reference soil.

- Existence of significant correlations between laboratory toxicity test results and concentrations of antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4,-DDE, and 4,4'-DDT or other chemical/physical characteristics of the tested soil (e.g., total organic carbon [TOC], pH, and grain size distributions).

Survival, growth, and reproduction of terrestrial avian omnivore populations:

- Comparison of modeled dietary intakes of cadmium, lead, mercury, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT using mean concentrations measured in earthworms maintained in site soil during toxicity testing with literature-based ingestion screening values.

Survival, growth, and reproduction of herbivorous West Indian manatee populations:

- Comparison of modeled dietary intakes of arsenic, cadmium, copper, mercury, selenium, and zinc using mean field-collected seagrass tissue concentrations with literature-based ingestion screening values.

4.1.2 SWMU 2 Measurement Endpoints

The proposed measurement endpoints selected for the baseline ERA at SWMU 2 are as follows:

Survival, growth, and reproduction of terrestrial invertebrate communities:

- Comparison of antimony, copper, lead, mercury, and zinc concentrations in surface and subsurface soil with invertebrate-based soil screening values and literature-based effect levels.

- Comparison of results of 28-day laboratory toxicity tests (survival, growth, and reproduction) with the earthworm *Eisenia fetida*, using site and reference soil.

- Existence of significant correlations between laboratory toxicity test results and concentrations of antimony, copper, lead, mercury, and zinc or other chemical/physical characteristics of the tested soil (e.g., TOC, pH, and grain size distributions).

Survival, growth, and reproduction of terrestrial avian omnivore populations:

- Comparison of modeled dietary intakes of copper, lead, mercury, and zinc using mean concentrations measured in earthworms maintained in site soil during toxicity testing with literature-based ingestion screening values.

Survival, growth, and reproduction of estuarine wetland benthic invertebrate communities:

- Comparison of copper, lead, and zinc concentrations in sediment with sediment screening values and literature-based effect levels.

- Comparison of simultaneously extracted metals (SEM; cadmium, copper, lead, nickel, silver, and zinc) sediment concentrations with AVS sediment concentrations.

- Comparison of results of 28-day sediment laboratory toxicity tests (survival, growth, and reproduction) with the burrowing amphipod *Leptocheirus plumulosus* and 20-day sediment laboratory toxicity tests (survival and growth) with the polychaete *Neanthes arenaceodentata*, using site and reference sediment.

- Existence of significant correlations between laboratory toxicity test results and concentrations of copper, lead, and zinc or other chemical/physical characteristics of the tested sediment (e.g., TOC, pH, and grain size distributions).

Survival, growth, and reproduction of estuarine wetland avian invertebrate consumers:

- Comparison of modeled dietary intakes of lead and mercury using mean concentrations measured in field collected fiddler crabs with literature-based ingestion screening values.

Survival, growth, and reproduction of herbivorous West Indian manatees:

- Comparison of modeled dietary intakes of arsenic, cadmium, copper, lead, mercury, selenium, and zinc using maximum concentrations measured in field-collected seagrass tissue concentrations with literature-based ingestion screening values.

4.2 Baseline Risk Assessment Study Design

A detailed description of the proposed sampling and analytical program is presented in Section 5.0. Field activities conducted as part of the baseline ERA at SWMUs 1 and 2 will include:

- Collection of surface soil and open water sediment at SWMU 1 for laboratory based analytical testing and collection of surface and subsurface soil, estuarine wetland sediment, and open water sediment at SWMU 2 for laboratory-based analytical testing.

  Although 4,4'-DDE and 4,4'-DDT in SWMU 1 subsurface soil were identified as potential ecological risk drivers, the baseline ERA study design for SWMU 1 does not include the collection of subsurface soil. This decision is based on existing analytical data, which show that maximum 4,4'-DDE and 4,4'-DDT concentrations were detected in surface soil (The maximum 4,4'-DDE and 4,4'-DDT concentration detected in SWMU 1 surface soil was 28,000 ug/kg and 43,000J ug/kg, respectively, while the maximum 4,4'-DDE and 4,4'-DDT concentration detected in SWMU 1 subsurface soil was 520 ug/kg and 3,500CD ug/kg, respectively [Baker, 2006a]).

  Both surface and subsurface soil samples will be collected at SWMU 2 because maximum concentrations for three metals identified as potential ecological risk drivers occurred in subsurface soil (Baker, 2006a): copper (919J mg/kg in surface soil and 5,850 mg/kg in subsurface soil); lead (4,760 mg/kg in surface soil and 5,850J mg/kg in subsurface soil); and zinc (1,140 mg/kg in surface soil and 3,350 mg/kg in subsurface soil).

- Collection of soil at SWMUs 1 and 2 for laboratory-based toxicological testing using the earthworm *Eisenia fetida*. This species was selected as the test organism for evaluating the toxicity and bioavailability of potential ecological risk drivers in SWMUs 1 and 2 surface soil and/or subsurface soil to terrestrial invertebrates for the reasons listed below:

  - The terrestrial invertebrate fauna of Puerto Rico includes eighteen endemic earthworm species (Blakemore, 2005).

  - A test method has been developed (American Society of Testing and Materials [ASTM], 2006) using *Eisenia fetida* with two sublethal endpoints (i.e., growth and reproduction), allowing for population-level risk evaluations on terrestrial invertebrates.

- Collection of estuarine wetland sediment at SWMU 2 for laboratory-based toxicological testing using the amphipod *Leptocheirus plumulosus* and the polychaete *Neanthes arenaceodentata*. These species were selected as test organisms for evaluating the toxicity and bioavailability of potential ecological risk drivers in SWMU 2 estuarine wetland sediment to benthic invertebrates for the reasons listed below:

  - *Leptocheirus plumulosus* and *Neanthes arenaceodentata* are infaunal species intimately associated with sediment due to their burrowing habits and sediment ingesting nature (USEPA, 2001, ASTM, 2000, and California Environmental Protection Agency [CEPA], 2004).

  - *Leptocheirus plumulosus* and *Neanthes arenaceodentata* are tolerant of a wide range of TOC, salinity, and grain size distributions (USEPA, 2001 and CEPA, 2004).

  - *Leptocheirus plumulosus* and *Neanthes arenaceodentata* have a high tolerance for ammonia, a naturally occurring compound in marine sediments that results from the degradation of organic debris (USEPA, 2001 and CEPA, 2004).

  - A chronic test method has been developed by the USEPA (2001) using *Leptocheirus plumulosus* with two sublethal endpoints (i.e., growth and reproduction) and a chronic test method has been developed by ASTM (2000) for *Neanthes arenaceodentata* with a single sublethal endpoint (growth), allowing for population-level risk evaluations on benthic invertebrates;

- Collection of earthworm (*Eisenia fetida*) tissue maintained in SWMUs 1 and 2 soil during toxicity testing for laboratory-based analytical testing. Earthworms are deemed an appropriate species for evaluating bioaccumulation and subsequent food web transfer of potential ecological risk drivers in SWMUs 1 and 2 soil to terrestrial avian omnivores based on their burrowing activities and feeding habits which expose them to soil contaminants. The collection of earthworm tissue samples from the upland terrestrial habitats at SWMUs 1 and 2 is preferable; however, observations recorded during previous field investigations has indicated that earthworm abundance is low and the collection of sufficient biomass for analytical testing is not likely to be possible. The availability of earthworms for field collection will be further evaluated during baseline ERA field sampling activities. If sufficient biomass is encountered at locations sampled during the baseline ERA field investigation, field collected earthworm tissue will be submitted for analytical testing in place of earthworm tissue maintained in SWMUs 1 and 2 soil during toxicity testing.

- Collection of fiddler crab (*Ulcer spp*.) tissue samples from estuarine wetland habitat at SWMU 2 for laboratory-based analytical testing. Fiddler crabs are deemed an appropriate species for evaluating bioaccumulation and subsequent food web transfer of potential ecological risk drivers in SWMU 2 estuarine wetland sediment to avian invertebrate consumers based on their burrowing activities which expose them to sediment contaminants, feeding habits, sedentary behavior, and presence in large numbers within estuarine wetland systems at NAPR.

- Collection of above ground and whole plant turtle grass tissue samples from open water habitat at SWMUs 1 and 2 for laboratory-based analytical testing. Foraging studies demonstrate that manatees in NAPR waters feed via two primary strategies depending on substrate firmness: (1) selective grazing of above ground shoots and stems only; or (2) rooting behavior and subsequent feeding on the entire plant, including roots and rhizomes (Geo-Marine Inc., 2005, Reid et al., 2001, and Mignucci-Giannoni and Beck, 1998). Selective above ground feeding behavior is characteristic of manatees observed in firm bottom habitats, where encrusting algae, coarser sediments, and/or more cohesive sediments are present (Reid et al., 2001). Although coarse and cohesive sediments are present within the open water portions of each SWMU and literature-based information indicates that West Indian manatees exhibit selective above ground feeding behavior within the Ensenada Honda (Reid et al., 2001), both above ground and whole plant tissue samples will be collected. Turtle grass was selected to evaluate West Indian manatee food web exposures at each SWMU for the reasons listed below:

    - Observations made during previous site visits and investigations indicate that turtle grass represents the dominant submerged aquatic vegetation species in Puerto Rican coastal waters in general and within the Ensenada Honda downgradient from SWMUs 1 and 2 (see Section 2.2.2).

    - Though manatees will forage on manatee grass, shoal grass, and green algae, they preferentially feed on turtle grass, even when it is not the dominant species. This preference is the same, across age classes and genders (Mignucci-Giannoni and Beck, 1998).

- Identification of suitable terrestrial, estuarine wetland, and open water reference areas, and the collection of soil and sediment at these locations for laboratory-based analytical and/or toxicological testing. Fiddler crab and seagrass tissue samples also will be collected from the estuarine wetland and open water reference areas for laboratory-based analytical testing.

4.3 Data Quality Objectives

The USEPA defines the Data Quality Objectives (DQO) process as a "*strategic approach based on the scientific method that is used to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerance level of decision errors for the study, and how many samples to collect*" (Barnthouse and Suter II, 1996).

The purpose of the DQO process is to ensure that the type, quantity, and quality of data used in the decision-making process will be appropriate for estimating potential ecological risks. By employing the DQO process, data requirements and error levels acceptable to the investigation can be defined prior to the collection of data. The DQO process is composed of seven steps (USEPA, 2000b and 2000c). These seven steps, as well as the general DQO process that will be applied to the baseline ERA for SWMUs 1 and 2 are outlined below:

- Step 1 - State the problem: Define the degree and spatial extent of any ecological risks from exposure to site-related chemicals in SWMUs 1 and/or 2 soil, estuarine wetland sediment, and open water sediment.

- Step 2 - Identify the decision: Is there evidence of unacceptable risk to ecological receptors? Are there sufficient data on which to base this decision?

- Step 3 - Identify the inputs: Analytical chemistry data from relevant media (soil, estuarine wetland sediment, open water sediment, earthworm tissue, fiddler crab tissue, and seagrass tissue), physical/chemical characteristics of exposure media, and toxicological testing.

- Step 4 - Define the boundaries of the study: Upland portion of SWMUs 1 and 2, estuarine wetland portion of SWMU 2, and open water portion of SWMUs 1 and 2.

- Step 5 - Develop a decision rule: Based upon the results of multiple lines of evidence for which data will be available, including (1) comparison of measured media concentrations to applicable risk-based screening values; (2) refined food web modeling using measured tissue concentrations; and (3) toxicological testing.

- Step 6 - Specify tolerable limits on decision errors: Acceptable data requirements and error levels associated with the field and analytical portions of this investigation are presented in the Master Plans (Baker, 1995). Acceptable data requirements and error levels associated with the laboratory-based toxicity tests (i.e., test conditions, data, and data interpretation) have been established by the USEPA (2001) and ASTM (2000 and 2006). Note that specific data requirements and error levels specified by the USEPA (2001) and ASTM (2000 and 2006) may vary from those identified by the procured laboratory's standard operating procedures (SOPs). Once a laboratory is procured, SOPs for the 28-day *Eisenia fetida* survival, growth, and reproduction test, 28-day *Leptocheirus plumulosus* survival, growth, and reproduction test, and 20-day *Neanthes arenaceodentata* survival and growth test will be provided to NAPR, Navy Base Realignment and Closure Program Management Office South East (BRAC PMO SE), and the USEPA prior to implementation of the Field Sampling and Analysis Plan (FSAP) presented in Section 5.0.

- Step 7 - Optimize the design for obtaining data: Compile and evaluate information and data to focus sampling efforts. Inherently optimized through the iterative nature of the 8-step ERA process.

4.4 Data Evaluation and Interpretation

The specific lines of evidence that will be employed at each SWMU and methods of evaluation are identified and discussed below.

SWMU 1:

- *Comparison of the spatial and statistical distributions of antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT concentrations in surface soil to literature-based terrestrial invertebrate toxicological thresholds* – analytical data for surface soil collected as part of the baseline ERA and existing analytical data for surface soil used in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a) will be combined into a unified data set. Maximum, mean, and 95 percent Upper Confidence Level (UCL) concentrations will be calculated for the combined data set (95 percent UCL concentrations will be derived using USEPA ProUCL Version 3.00.02 software available at http://www.epa.gov/nerlesd1/tsc/software.htm). The spatial pattern of detections and exceedances of relevant criteria will be evaluated along with these statistical parameters. The antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT soil screening values used in the comparison will be the following:

    - Antimony: 78 mg/kg – Eco-SSL for soil invertebrates (USEPA, 2005a)
    - Cadmium: 20 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)
    - Copper: 50 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)
    - Lead: 200 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)
    - Mercury: 0.1 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)

- o <u>Tin</u>: Toxicological benchmarks and literature-based toxicity data are not available for tin. A literature-based toxicological benchmark for terrestrial plants (50 mg/kg; Efroymson et al., 1997a) will be used as a surrogate.

- o <u>Zinc</u>: 200 mg/kg – Toxicological threshold for earthworms (Efroymson et al., 1997b)

- o <u>4,4'-DDD</u>: 400 mg/kg – Mean of the target and intervention value for total DDT/DDD/DDE in a standard soil (MHSPE, 2,000)

- o <u>4,4'-DDE</u>: 400 mg/kg – Mean of the target and intervention value for total DDT/DDD/DDE in a standard soil (MHSPE, 2000)

- o <u>4,4'-DDT</u>: 400 mg/kg – Mean of the target and intervention value for total DDT/DDD/DDE in a standard soil (MHSPE, 2,000)

- *Comparison of Eisenia fetida survival, growth, and reproduction data in SWMU 1 surface soil to that in reference soil* – Statistical comparisons between SWMU 1 surface soil samples and their assigned reference sample will be conducted for survival, growth, and reproduction of *Eisenia fetida*. The statistical tests (specified by the toxicity testing laboratory SOP [see Section 5.4]) will determine whether organism performance is significantly reduced (at α = 0.05) when exposed to surface soil collected from SWMU 1 relative to the reference area.

- *Existence of patterns in Eisenia fetida laboratory toxicity test results with chemical burdens and other chemical/physical characteristics of SWMU 1 surface soil* – The data will be reviewed to determine whether there are relationships between biological response in the toxicity tests and antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT content of surface soil at SWMU 1. This will be done with the use of multiple regressions or other appropriate statistical analyses. Other factors that may be considered in the analyses include pH, TOC, and grain size distributions. Analysis of correlations between chemical concentrations and toxicity test results (considering the most sensitive of measured endpoints) will be used to determine effect levels for antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in surface soil at SWMU 1.

- *Comparison of dietary intakes for terrestrial avian omnivores and West Indian manatees to literature-based toxicity reference values*. Mean concentrations in earthworm tissue (cadmium, lead, mercury, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) and maximum concentrations in turtle grass tissue (arsenic, cadmium, copper, mercury, selenium, and zinc) will be used in place of modeled values to estimate dietary intakes for terrestrial avian omnivores and West Indian manatees, respectively. Dietary intakes for each upper trophic level receptor species will be estimated using the following formula modified from USEPA (1993):

$$DI_x = \frac{[[\sum_i (FIR)(FC_{xi})(PDF_i)] + [(FIR)(SC_x)(PDS)][AUF]}{BW}$$

where:

DI_x	=	Dietary intake for chemical x (mg chemical/kg body weight/day)
FIR	=	Food ingestion rate (kilograms per day [kg/day], dry-weight)
FC_{xi}	=	Concentration of chemical x in food item i (dry weight basis)
PDF_i	=	Proportion of diet composed of food item i (mg/kg, dry weight)

SC_x	=	Concentration of chemical x in soil/sediment (mg/kg, dry weight)
PDS	=	Proportion of diet composed of soil/sediment (dry weight basis)
BW	=	Body weight (kg, wet weight)
AUF	=	Area Use Factor (unitless)

The American robin will be used as representative species for terrestrial avian omnivore populations. Exposure parameters and diet assumptions for the American robin and West Indian manatee are summarized in Tables 4-1 and 4-2, respectively. Although omnivorous, prey consumed by the American robin is assumed to be 100 percent earthworms in this baseline ERA. Direct ingestion of drinking water is only considered if the salinity of a drinking water source is less than 15 ppt, the approximate toxic threshold for wildlife receptors (Humphreys, 1988). As discussed in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a), no potential drinking water sources are located within or contiguous to SWMUs 1 and 2. As such, ingestion of surface water is not a potential complete exposure pathway and will not be considered in risk calculations for dietary exposures. For the baseline ERA, an AUF of 1.0 will be assumed (i.e., each receptor is assumed to spend 100% of its time within SWMU 1 and/or 2, an overly conservative assumption).

Ingestion-based HQs for the American robin will be calculated by dividing mean dietary intakes by literature-based NOAEL and LOAEL values, while ingestion-based HQs for the West Indian manatee will be calculated by dividing maximum dietary intakes by literature-based NOAEL values adjusted to reflect differences in body weights between the mammalian test species and the West Indian manatee (Baker, 2006a). Based on the endangered species status of the West Indian manatee, NOAEL values are most appropriate for this receptor. The NOAEL and/or LOAEL values that will be used in the derivation of HQ values are summarized in Tables 4-3 (American robin) and 4-4 (West Indian manatee).

It is noted that the SWMU 1 is located within the critical habitat designation of the yellow-shouldered blackbird. Based on aspects of the feeding ecology of the American robin and yellow-shouldered blackbird, as well as the diet assumptions summarized in Table 4-2 for the American robin (see items listed below), the American robin can be protectively used as a surrogate receptor for the yellow-shouldered blackbird.

- o The diet of the American robin is assumed to be 90.1 percent invertebrates (i.e., earthworms) and 9.1 percent soil. Available literature (USFWS, 1996) indicates that the diet of the yellow shouldered blackbird is 90 percent invertebrates and 10 percent plant material. Soil consumption by the yellow shouldered blackbird is assumed to be negligible based on their arboreal feeding behavior (see second bullet item below). As such, the assumed diet of the American robin (90.9 percent invertebrates and 9.1 percent soil) will result in a conservative estimate of food web exposures for the yellow shouldered blackbird.

- o The American robin forages primarily on the ground for soft-bodied invertebrates (e.g., earthworms), whereas the yellow shouldered blackbird is an arboreal feeder that forages within the canopy and sub-canopy layers of trees (USFWS, 1996). As above, prey items consumed by the American robin are assumed to be 100 percent earthworms. Because earthworms are in direct contact with soil, they will bioaccumulate soil contaminants at higher concentrations than arboreal invertebrates. Therefore, modeled dietary intakes for the American robin based on the ingestion of earthworms will result in conservative estimate of food web exposures for the yellow shouldered blackbird.

SWMU 2:

- *Comparison of the spatial and statistical distributions of antimony, copper, lead, mercury, and zinc concentrations in SWMU 2 surface and subsurface soil to terrestrial invertebrate-based toxicological thresholds* – Analytical data for surface soil and subsurface soil collected as part of the baseline ERA and existing analytical data for surface and subsurface soil used in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a) will be combined into unified data sets. Maximum, mean, and 95 percent UCL concentrations will be calculated for each data set (95 percent UCL concentrations will be derived using USEPA ProUCL Version 3.00.02 software). The spatial pattern of detections and exceedances of relevant criteria will be evaluated along with these statistical parameters. The antimony, copper, lead, mercury, and zinc soil screening values used in the comparison will be the following:

    - Antimony: 78 mg/kg – Eco-SSL for soil invertebrates (USEPA, 2005a)

    - Copper: 50 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)

    - Lead: 200 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)

    - Mercury: 0.1 mg/kg – Toxicological benchmark for earthworms (Efroymson et al., 1997b)

    - Zinc: 200 mg/kg – Toxicological threshold for earthworms (Efroymson et al., 1997b)

- *Comparison of Eisenia fetida survival, growth, and reproduction data in SWMU 2 surface and subsurface soil to that in reference soil* – Statistical comparisons between SWMU 2 surface and subsurface soil samples and their assigned reference sample will be conducted for survival, growth, and reproduction of *Eisenia fetida*. The statistical tests (specified by the toxicity testing laboratory SOP [see Section 5.4]) will determine whether organism performance is significantly reduced (at $\alpha = 0.05$) when exposed to surface and subsurface soil collected from SWMU 2 relative to the reference area.

- *Existence of patterns in Eisenia fetida laboratory toxicity test results with chemical burdens and other chemical/physical characteristics of SWMU 2 surface and subsurface soil* – The data will be reviewed to determine whether there are relationships between biological response in the toxicity tests and antimony, copper, lead, mercury, and zinc content of surface and subsurface soil at SWMU 2. This will be done with the use of multiple regressions or other appropriate statistical analyses. Other factors that may be considered in the analyses include pH, TOC, and grain size distributions. Analysis of correlations between chemical concentrations and toxicity test results (considering the most sensitive of measured endpoints) will be used to determine effect levels for antimony, copper, lead, mercury, and zinc in surface and subsurface soil at SWMU 2.

- *Comparison of the spatial and statistical distributions of copper, lead, and zinc in SWMU 2 estuarine wetland sediment to benthic invertebrate-based toxicological thresholds* – Analytical data for sediment collected as part of the baseline ERA and existing analytical data for sediment used in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a) will be combined into a unified data set. Maximum, mean, and 95 percent UCL concentrations will be calculated from the unified data set (95 percent UCL concentrations will be derived using USEPA ProUCL Version 3.00.02 software). The spatial pattern of detections and exceedances of relevant criteria will be evaluated along with these statistical parameters. The copper, lead, and zinc sediment screening values used in the comparison will be the following:

- o <u>Copper</u>: 18.7 mg/kg – Marine TEL (MacDonald, 1994)
- o <u>Lead</u>: 30.2 mg/kg – Marine TEL (MacDonald, 1994)
- o <u>Zinc</u>: 124 mg/kg – Marine TEL (MacDonald, 1994)

- *Derivation of Acid Volatile Sulfide (AVS)-Simultaneously Extracted Metal (SEM) ratios to assess the bioavailability of bulk copper, lead, and zinc concentrations in SWMU 2 estuarine wetland sediment* – The AVS/SEM model states that if the AVS concentration is greater than the concentration of SEM (cadmium, copper, lead, nickel, silver, and zinc), toxicity will not be observed. That is, if the ratio AVS/SEM is greater than 1.0, sufficient AVS is available to bind all the SEM and sediment-associated biota are not likely to be exposed to toxic concentrations of these metals in the sediment pore water. Conversely, if the ratio AVS/SEM is less than 1.0, insufficient AVS is present to bind all SEM. The AVS/SEM data will be evaluated on a sample by sample basis, allowing for the identification of spatially explicit areas where copper, lead, and zinc are or are not bioavailable.

- *Comparison of Leptocheirus plumulosus survival, growth, and reproduction data and Neanthes arenaceodentata survival and growth data in SWMU 2 estuarine wetland sediment to that in reference sediment* – Statistical comparisons between SWMU 2 estuarine wetland sediment samples and their assigned reference sample will be conducted for survival, growth, and reproduction of *Leptocheirus plumulosus* and survival and growth of *Neanthes arenaceodentata*. The statistical tests (specified by the toxicity testing laboratory SOP [see Section 5.4]) will determine whether organism performance is significantly reduced (at α = 0.05) when exposed to estuarine wetland sediment collected from SWMU 2 relative to the reference area.

- *Existence of patterns in Leptocheirus plumulosus and Neanthes arenaceodentata laboratory toxicity test results with chemical burdens and other chemical/physical characteristics of estuarine wetland sediment* – The data will be reviewed to determine whether there are relationships between biological response in the toxicity tests and copper, lead, and zinc content of SWMU 2 estuarine wetland sediment. This will be done with the use of multiple regressions or other appropriate statistical analyses. Other factors that may be considered in the analyses include AVS/SEM ratios, ammonia, sulfide, pH, TOC, redox potential, salinity of the overlying water column, and grain size distributions. Analysis of correlations between chemical concentrations and toxicity test results (considering the most sensitive of measured endpoints for each species) will be used to determine effects levels for copper, lead, and zinc in SWMU 2 estuarine wetland.

- *Comparison of dietary intakes for terrestrial avian omnivores, aquatic avian invertebrate consumers, and West Indian manatees to literature-based toxicity reference values*. Mean concentrations in earthworm tissue (copper, lead, mercury, and zinc), mean concentrations in fiddler crab tissue (lead and mercury), and maximum concentrations in turtle grass tissue (arsenic, cadmium, copper, lead, mercury, selenium, and zinc) will be used in place of modeled values to estimate dietary intakes for terrestrial avian omnivores, aquatic avian invertebrate consumers, and West Indian manatees, respectively. Dietary intakes for each upper trophic level receptor species will be estimated using the following formula modified from USEPA (1993):

$$DI_x = \frac{[[\sum_i (FIR)(FC_{xi})(PDF_i)] + [(FIR)(SC_x)(PDS)][AUF]}{BW}$$

where:

DI_x	=	Dietary intake for chemical x (mg chemical/kg body weight/day)
FIR	=	Food ingestion rate (kilograms per day [kg/day], dry-weight)
FC_{xi}	=	Concentration of chemical x in food item i (dry weight basis)
PDF_i	=	Proportion of diet composed of food item i (mg/kg, dry weight)
SC_x	=	Concentration of chemical x in soil/sediment (mg/kg, dry weight)
PDS	=	Proportion of diet composed of soil/sediment (dry weight basis)
BW	=	Body weight (kg, wet weight)
AUF	=	Area Use Factor (unitless)

The American robin and spotted sandpiper will be used as representative species for terrestrial avian omnivore and aquatic avian invertebrate consumer populations. Exposure parameters and diet assumptions for the American robin, spotted sandpiper, and West Indian manatee are summarized in Tables 4-1 and 4-2, respectively. Although omnivorous, prey consumed by the American robin is assumed to be 100 percent earthworms in this baseline ERA. Direct ingestion of drinking water is only considered if the salinity of a drinking water source is less than 15 ppt, the approximate toxic threshold for wildlife receptors (Humphreys, 1988). As discussed in the screening-level ERA and Step 3a of the baseline ERA (Baker, 2006a), no potential drinking water sources are located within or contiguous to SWMU 2. As such, ingestion of surface water is not a potential complete exposure pathway and will not be considered in risk calculations for dietary exposures. For the baseline ERA, an AUF of 1.0 will be assumed (i.e., each receptor is assumed to spend 100% of its time within SWMU 2, an overly conservative assumption).

Ingestion-based HQs for the American robin and spotted sandpiper will be calculated by dividing mean dietary intakes by literature-based NOAEL and LOAEL values, while ingestion-based HQs for the West Indian manatee will be calculated by dividing maximum dietary intakes by literature-based NOAEL and LOAEL values adjusted to reflect differences in body weights between the mammalian test species and the West Indian manatee (Baker, 2006a). The NOAEL and LOAEL values that will be used in the derivation of HQ values are summarized in Tables 4-3 (American robin and spotted sandpiper) and 4-4 (West Indian manatee).

Identical to SWMU 1, SWMU 2 is located within the critical habitat designation of the yellow-shouldered blackbird. For the reasons discussed above for SWMU 1, the American robin can be protectively used as a surrogate receptor for the yellow-shouldered blackbird.

Table 4-5 summarizes the decision rules and criteria that will be used to outline potential recommendations and actions associated with these lines of evidence. In general, each of the lines of evidence will be weighted equally. However, the following considerations to weight will be given once analytical results are compiled and all statistical tests are completed:

- Exposure-Response - Data that demonstrates a clear, unconfounded dose-relationship between the response variable and the potential ecological risk driver will be preferentially weighted at the decision point.

- Quality - Data sets that meet the acceptable data requirements and error levels outlined in the Master DCQAP (Baker, 1995) and the procured toxicity testing laboratory's SOPs will be preferentially weighted at the decision point.

- Power - Data sets of sufficient size and coverage to detect a statistical difference between groups of interest will be preferentially weighted at the decision point. For the *Leptocheirus plumulosus* and *Neanthes arenaceodentata* toxicity tests, minimum statistical difference (MSD) values (mean range and 90th percentile MSDs) will be derived for each endpoint. The MSD reflects the statistical power of toxicity tests by determining the magnitude of difference from the control determined to be statistically significant. For a given endpoint, higher variability in test data leads to higher MSD values and decreases statistical power. Conclusions regarding the acceptability of risk based on toxicity test data will give a greater weight to the endpoint exhibiting the greatest statistical power.

- Spatial coverage - Data sets that adequately characterized the concentration gradient of the identified risk drivers will be preferentially weighted at the decision point.

- Uncertainty - Data sets relating to the assessment endpoints with lower uncertainty will be preferentially weighted at the decision point.

If significant conflicts among the lines of evidence result in uncertain risk conclusions, the risk managers will need to decide if these uncertainties are too high. If so, additional data collection and evaluation beyond the proposed sampling might be required to resolve the uncertainties.

5.0 FIELD SAMPLING AND ANALYSIS PLAN

This section presents the proposed field and laboratory activities for the baseline ERA at SWMUs 1 and 2. Activities will include fieldwork support (subcontractor procurement and mobilization/demobilization), field verification of the FSAP, field investigations, analytical testing and data validation, data evaluation, and report preparation. The primary purpose of the FSAP is to provide guidance for all the project field activities by describing in detail the methods and procedures to be used to implement various field tasks for SWMUs 1 and 2.

To simplify the process of developing site-specific project plans, Master Plans have been prepared for project management (PMP), DCQAP, DMP, and HASP (Baker, 1995). Together, these plans provide all details regarding field investigation techniques, laboratory analysis, data validation, and data evaluation required to fulfill the requirements of the RFI program. These plans provide the details for sampling and analysis protocols to be followed and general activities to be accomplished for the baseline ERAs at SWMU 1 and 2. Addendums to the DCQAP and HSAP have been prepared to address specific issues related to this investigation (see Appendix A and Appendix B, respectively). This document will supplement the Master Plans with site-specific information for the SWMUs 1 and 2 baseline ERA.

5.1 Field Work Support

Field work support includes subcontractor procurement and mobilization/demobilization. Subcontractors procured for the baseline ERA at SWMUs 1 and 2 will consist of: (1) an analytical laboratory; (2) a third party, independent data validator; and (3) a toxicity testing laboratory. Mobilization/demobilization activities will include procurement of equipment and supplies necessary for the field sampling program, and shipping or transporting those items to and from the field.

5.2 Verification of the Field Sampling Design

Prior to implementation of the baseline ERA field investigations at SWMUs 1 and 2 (see Section 5.3), the sampling design will be verified in the field (Step 5 of the ERA process) to ensure that the study design is appropriate and can be implemented at the site. The testable hypotheses, exposure pathway models, and measurement endpoints also will be evaluated for their appropriateness.

The toxicity tests and tissue residual samples identified in Section 5.3 require that sediment and tissue samples from areas not known to be impacted by identified contaminant sources (i.e. SWMUs 1 and 2), termed reference areas, be collected for comparison to potentially impacted areas. Based on the baseline ERA study design, reference areas must be established within three distinct habitats: (1) upland coastal scrub/upland coastal forest habitat; (2) estuarine wetland habitat; and (3) open water habitat. Upland, estuarine wetland, and open water reference areas have been identified based on the lack of contaminant influences and the likely availability of habitat similar to that present at SWMUs 1 and 2. The suitability of these potential reference areas will be evaluated during verification of the field sampling design. Specific activities conducted within the proposed reference areas and SWMUs 1 and 2 are discussed below (a sample summary is provided in Table 5-1). Verification of the baseline ERA field sampling design at each SWMU will be conducted simultaneously (i.e., during the same field trip).

Upland Reference Area and Upland Portions of SWMUs 1 and 2

Three potential upland reference areas (see Figure 5-1) have been identified based on the lack of potential contaminant influences from SWMUs 1 and 2 and the presence of upland coastal scrub and/or upland coastal forest communities (as determined by a review of Figures 2-3 and 2-4). The upland reference areas border the same estuarine wetland system located downgradient from the upland portions of SWMUs 1 and 2. A maximum of 4 surface soil and 4 subsurface soil samples will be collected from each area (total of 12 surface soil and 12 subsurface soil samples). At each of the upland reference areas, fifty percent of the proposed surface and subsurface soil samples will be analyzed for antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, TOC, pH, and grain size. The metals and organochlorine pesticides listed above represent the potential ecological risk drivers identified in Step 3b of the ERA process for SWMUs 1 and/or 2 surface and subsurface soil. Because soil quality at the proposed upland reference areas has not been characterized during previous investigations at NAPR, unknown soil contaminants may be present at these locations. As such, fifty percent of the proposed surface and subsurface soil samples at each upland reference area will be analyzed for low level polycyclic aromatic hydrocarbons (LL-PAHs), Appendix IX organochlorine pesticides, and Appendix IX metals. These chemical classes include the potential ecological risk drivers identified for SWMUs 1 and 2 surface and/or subsurface soil, as well as those parameters detected in SWMUs 1 and 2 surface and/or subsurface soil at a high frequency. It is noted that the proposed upland reference areas are located within undeveloped land, outside the potential influence of SWMUs 1 and 2 (i.e., topographically upgradient of impacted SWMUs 1 and 2 soils). Furthermore, the proposed reference areas are remote form other SWMUs/Areas of Concern (AOCs) identified at NAPR. Finally, surrounding land uses are limited to undeveloped land, residential properties, and commercial properties (e.g., Navy Lodge, Navy Exchange, and Commissary). For these reasons, additional parameters beyond the proposed LL-PAHs, Appendix IX organochlorine pesticides, and Appendix IX metals are not deemed necessary to demonstrate the adequacy of the proposed upland reference areas for use in the baseline ERA. Sample locations within a given reference area will be chosen to be as similar as possible to the upland portions of SWMUs 1 and 2 with regard to vegetation, vegetative cover, and visual soil characteristics (i.e., color and texture).

Existing surface and subsurface soil analytical data for SWMUs 1 and 2 do not include TOC, pH, and grain size data. Therefore, as part of the field verification, a maximum of six surface soil samples will be collected from the upland portions of each SWMU (total of twelve samples) and analyzed for these parameters. Six subsurface soil samples also will be collected from the upland portion of SWMU 2 and analyzed for TOC, pH and grain size. Subsurface soil samples will not be collected from SWMU 1 since proposed baseline ERA field sampling activities within the upland portion of this SWMU does not include subsurface soil collection (see Section 5.3.1).

For a given upland reference area to be considered appropriate, the following conditions must be met: (1) habitat offered by the reference area must be similar to habitat found within the upland portions of SWMUs 1 and 2 with regard to vegetation and vegetative cover; (2) the reference soil samples must exhibit a range of TOC concentrations and grain size characteristics similar to the ranges found in soil samples collected at SWMUs 1 and 2; and (3) the concentration of Appendix IX metals in reference soil (surface and subsurface soil) must not be statistically elevated above background soil concentrations, while the concentration of LL-PAHs and Appendix IX organochlorine pesticides in reference soil must not be detected at concentrations that exceed toxicological thresholds (i.e., screening values) previously established in Step 1 of the ERA process (Baker, 2006a). The background surface and subsurface soil data used in the statistical evaluation will be the background data set presented and discussed within the *Final Summary Report for Environmental Background Concentrations of Inorganic Compounds* (Baker, 2006b). Statistical evaluations will be conducted in accordance with Navy guidance (NFESC, 2002; see Figure 5-2).

Estuarine Wetland Reference Area and Estuarine Wetland Portion of SWMU 2

The proposed estuarine wetland reference area (see Figure 5-1) was previously identified as the base background sampling location for estuarine wetland sediment and is located outside potentially impacted areas (as determined by analytical data for background sediment samples collected from this area during the SWMU 9 Corrective Measures Study (CMS) field investigation [Baker, 2003]). A maximum of six sediment samples will be collected within the proposed reference area and analyzed for total copper, lead, mercury, and zinc, as well as ammonia, sulfide, pH, TOC, and grain size. Reference sediment sample locations will be chosen to be as similar as possible to the estuarine wetland system downgradient from SWMU 2 with regard to vegetation, vegetative cover, depth of overlying water, and visual sediment characteristics (e.g., color and texture). The variability in habitat and variability in visual sediment characteristics will dictate the actual number of reference sediment samples collected. In addition to the reference samples, a maximum of six sediment samples will be collected from the estuarine wetland system downgradient from SWMU 2 and analyzed for ammonia, sulfide, pH, and grain size. SWMU 2 estuarine wetland sediment will not be analyzed for TOC as a sufficient TOC data set is available to establish the range of TOC concentrations (Baker, 2006a).

For the proposed estuarine wetland reference area to be considered appropriate, the following conditions must be met: (1) habitat offered by the reference area must be similar to habitat found within the estuarine wetland system downgradient from SWMU 2 with regard to vegetation, vegetative cover, and depth of overlying water; (2) the reference sediment samples must exhibit a range of ammonia, sulfide, and TOC concentrations and grain size characteristics similar to the ranges found in SWMU 2 estuarine wetland sediment; and (3) the concentration of potential ecological risk drivers in reference sediment must not be statistically elevated above background estuarine wetland sediment concentrations. The background estuarine wetland sediment data used in the statistical evaluation will be the background data set presented and discussed within the *Final Summary Report for Environmental Background Concentrations of Inorganic Compounds* (Baker, 2006b). Statistical evaluations will be conducted in accordance with Navy guidance (NFESC, 2003; see Figure 5-2).

Open Water Reference Area and Open Water Portions of SWMUs 1 and 2

Three potential open water reference areas have been identified based on the lack of potential contaminant influences from SWMUs 1 and 2 and the presence of seagrass (as determined by field observations and review of Figures 2-3 and 2-4). These three reference areas, identified on Figure 5-1, will be sampled at part of the verification of the field sampling design for a baseline ERA that is being conducted at SWMU 45 (see Baker, 2006b). The sediment samples collected from the proposed open water reference areas as part of the SWMU 45 field verification (six samples from each area [total of 18 sediment samples]) will include analyses for the potential ecological risk drivers identified at SWMUs 1 and/or 2 for West Indian manatee food web exposures (i.e., arsenic, cadmium, copper, lead, mercury, selenium, and zinc), as well as TOC and grain size. A qualitative seagrass survey also will be performed at each of the proposed open water reference areas during the SWMU 45 field verification to ensure that available West Indian manatee foraging habitat is similar to that offered within the open water portions of SWMUs 1 and 2 (climax turtle grass community). Additional sample collection activities within the proposed open water reference areas are not anticipated during field verification of the SWMUs 1 and 2 sampling design. Additional sample collection activities within the open water portion of each SWMU also are not anticipated as a sufficient data set is available to establish the range of TOC concentrations and grain size characteristics (Baker, 2006a).

For a given open water reference area to be considered appropriate, the following conditions must be met: (1) the habitat offered by the reference area must be similar to habitat found within the open water portions of SWMUs 1 and 2 (climax turtle grass community); (2) the open water reference sediment samples must exhibit a range of TOC concentrations and grain size characteristics similar to the ranges found in SWMUs 1 and 2 open water sediment; and (3) the concentration of potential ecological risk drivers in reference sediment must not be statistically elevated above background open water sediment concentrations. The background open water sediment data used in the statistical evaluation will be the background data set presented and discussed within the *Final Summary Report for Environmental Background Concentrations of Inorganic Compounds* (Baker, 2006b). Statistical evaluations will be conducted in accordance with Navy guidance (NFESC, 2003; see Figure 5-2).

By verifying the field sampling design prior to conducting the field investigation, well-considered alterations to the study design can be made if necessary. If the field verification indicates that the study design cannot be met, or that significant deviations from this FSAP are necessary, discussion will be held with representatives from NAPR, Navy BRAC PMO SE, Baker, and USEPA to determine appropriate actions. If the requirements for contaminant concentrations and the physical/chemical/biological properties are not met at a given proposed reference area (upland, estuarine wetland, or open water reference areas), alternate reference areas will be established within an unimpacted portions of each SWMU during the baseline ERA field investigation (as determined by analytical results). An alternate reference area will be considered acceptable if it meets the requirements noted above.

5.3 Baseline Ecological Risk Assessment Field Investigations

Field sampling activities at SWMU 1 will involve the collection of surface soil, open water sediment, and seagrass tissue, while field activities at SWMU 2 will involve the collection of surface and subsurface soil, estuarine wetland sediment, open water sediment, fiddler crab tissue, and seagrass tissue. Abiotic (surface and subsurface soil, estuarine wetland sediment, and open water sediment) and biotic media (fiddler crab tissue and seagrass tissue) also will be collected from appropriate reference areas. Field data collection activities will be recorded in a project logbook. Entries will be described at an appropriate level of detail so that the situation can be reconstructed without reliance on memory. A discussion of the proposed sampling activities at each SWMU is presented in the sections that follow. It is noted that baseline ERA field sampling activities at SWMUs 1 and 2 will not be conducted during the same sampling event. Separation of sampling activities is necessary due to the large number of samples required at each SWMU and the need for quick-turn analyses by the procured analytical laboratory.

5.3.1 SWMU 1 Baseline Ecological Risk Assessment Field Investigation

Surface soil samples will be collected within the upland habitat at SWMU 1 to evaluate terrestrial invertebrate direct contact exposures to antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. Seagrass tissue and sediment samples also will be collected from the open water portion of SWMU 1 to evaluate West Indian manatee food web exposures to arsenic, cadmium, copper, mercury, selenium, and zinc. In addition to these SWMU-specific samples, surface soil, open water sediment, and seagrass tissue will be collected from appropriate reference areas. A sample summary is presented in Table 5-2.

5.3.1.1 Surface Soil

A maximum of 55 surface soil samples (0 to 1.0 foot below ground surface [bgs]) will be collected from the upland habitat at SWMU 1. Sample locations will be identified by establishing four 10-foot by 10-foot sampling grids centered around each of 11 sampling points previously sampled during the 1996 RFI field investigation or the 2004 additional data collection field effort (1SS04, 1SS06, 1SS07, 1SD01, 1SD02, 1SS09, 1SS10, 1SS11, 1SS12, 1SS13, and 1SS16 [see Figure 5-3]). The concentrations of potential surface soil ecological risk drivers (i.e., antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) at these 11 sampling points span the range of concentrations detected in surface soil collected during previous investigations (see Table 3-1). At each historical sampling point, 5 surface soil samples will be collected (one from each of the four 10-foot by 10-foot sampling grids and one from the grid system's center point [approximate location of the historical sampling point]). The location sampled within each grid will be determined in the field and will be biased toward potential depositional areas (i.e., depressions/low points). In addition to the SWMU-specific surface soil samples, a maximum of six surface soil samples will be collected from one or more of the proposed upland reference areas identified on Figure 5-1. The criteria used to determine if a given reference area is appropriate were previously discussed in Section 5.2.

The SWMU 1 and reference area surface soil samples will be collected using dedicated stainless steel spoons or stainless steel hand augers. Specific sampling equipment used at a given sampling point will be dictated by the conditions encountered in the field (e.g., degree of soil compaction). Each sample will be homogenized in aluminum pans in the field and split between (1) a smaller portion submitted to the analytical laboratory for quick-turn (48-hour) antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT analyses (including associated Quality Assurance/Quality Control [QA/QC] samples); and (2) a larger portion held in a sealed storage container on ice until results of the quick-turn analyses are available. Upon receipt of the analytical results, a maximum of 10 SWMU 1 surface soil samples and 3 reference area surface soil samples will be selected and submitted to the toxicity testing laboratory for 28-day *Eisenia* f*etida* survival, growth, and reproduction tests. A portion of each sample submitted for toxicity testing also will submitted to the analytical laboratory for TOC, pH, and grain size analyses. The SWMU 1 surface soil samples submitted for toxicity and analytical testing will come from the portions held on ice while waiting for quick-turn analytical results and will be selected to capture the gradient of antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT concentrations measured at the site. Determination of the capture of a suitable concentration gradient will be based on obtaining surface soil samples with concentrations ranging from below invertebrate-based screening values (see Section 4.4) on the lower end to equaling or exceeding the 95 percent UCL of the existing dataset (i.e., dataset used in Step 2 and Step 3a of the baseline ERA [Baker, 2006a]) on the upper end. 95 percent UCL values used in this determination will be derived using USEPA ProUCL Version 3.00.02 software.

The reference area surface soil samples submitted for toxicity testing also will come from the portions held on ice while waiting for quick-turn analytical results. A given reference area surface soil sample will be considered appropriate for toxicological testing if: (1) the antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT concentration in that sample is less than the terrestrial invertebrate-based screening values identified in Section 4.4; and (2) the TOC concentration, pH, and grain size characteristics of that sample are similar to one or more of the SWMU 1 surface soil samples selected for toxicity testing. The range of TOC concentrations, pH values, and grain size characteristics encountered in the SWMU 1 surface soil samples selected for toxicity testing will dictate that actual number of reference samples submitted for *Eisenia fetida* toxicity testing.

5.3.1.2 <u>Seagrass Tissue and Open Water Sediment</u>

A maximum of six composite turtle grass samples will be collected from three locations within the open water portion of SWMU 1 (one above ground plant composite sample and one whole-body-plant composite per sample location). A maximum of six composite turtle grass samples also will be collected from three locations established within one or more of the open water reference areas identified on Figure 5-1 (one above ground plant composite sample and one whole-body-plant composite per sample location). The criteria used to determine if a given open water reference area is appropriate for use in this baseline ERA were previously discussed in Section 5.2. Compositing of plant samples will be necessary to achieve the desired tissue mass (2 to 5 grams wet weight) for analysis. Above ground seagrass tissue will be collected by shearing plants at the sediment-water interface using a sharp blade. Whole-plant samples will be collected with a rake and/or shovel, depending on the depth of the water column and firmness of the sediment and rhizome layer. As discussed in Section 4.2, turtle grass will be targeted for tissue collection as it is the preferred manatee forage species and is the dominant species found within the open water portion of SWMU 1. Tissue samples will be rinsed in distilled water, wrapped in aluminum foil, placed in freezer bags, frozen in a freezer prior to shipment to the analytical laboratory, and packed with ice to remain frozen during shipment. Each above ground and whole-body tissue composite sample (SWMU-specific and reference area samples) will be analyzed for total arsenic, cadmium, copper, mercury, selenium, and zinc, as well as percent moisture. Seagrass tissue will not be collected from the open water reference areas during baseline ERA field sampling activities at SWMU 2 (see Section 5.3.2.3). As such, reference area seagrass tissue also will be analyzed for the potential ecological risk drivers unique to SWMU 2 (i.e., lead).

A single surface sediment composite sample (0 to 6 inches bgs) will be collected at each SWMU 1 and reference area seagrass sampling location immediately following seagrass collection activities using dedicated hand corers. Sediment from each location will be homogenized in aluminum pans and submitted to the analytical laboratory and analyzed for total arsenic, cadmium, copper, mercury, selenium, zinc, TOC, and grain size. Associated field QA/QC samples (i.e., field duplicates and matrix spike/matrix spike duplicates [MS/MSDs]) also will be analyzed for total arsenic, cadmium, copper, mercury, selenium, and zinc. Identical to seagrass tissue, sediment will not be collected from the open water reference areas during baseline ERA field sampling activities at SWMU 2. As such, all open water reference area sediment samples also will be analyzed for the potential ecological risk drivers unique to SWMU 2 (i.e., lead).

It is noted that arsenic, cadmium, copper, mercury, selenium, and zinc concentrations detected in SWMU 1 open water sediment collected during previous investigations (Baker, 2006a) exhibit a fairly uniform concentration distribution throughout the open water portion of SWMU 1. As such, specific locations are not targeted for sampling based on analytical chemistry. Sample locations will be selected in field based on the presence of turtle grass.

5.3.2 SWMU 2 Baseline Ecological Risk Assessment Field Investigation

Surface and subsurface soil samples will be collected within the upland portion of SWMU 2 to evaluate terrestrial invertebrate direct contact exposures to antimony, copper, lead, mercury, and zinc. Sediment samples also will be collected within the estuarine wetland portion of SWMU 2 to evaluate benthic invertebrate direct contact exposures to copper, lead, and zinc. In addition to sediment, fiddler crab tissue samples will be collected from the estuarine wetland portion of SWMU 2 to evaluate avian aquatic invertebrate consumer food web risks to lead and mercury in sediment. Finally, seagrass and sediment samples will be collected from the open water portion of SWMU 2 to evaluated West Indian manatee food web exposures to arsenic, cadmium, copper, lead, mercury, selenium, and zinc. In addition to these SWMU-specific samples, surface soil, subsurface soil, estuarine wetland sediment, and fiddler crab tissue will be collected from appropriate reference areas. A sample summary is presented in Table 5-3.

5.3.2.1 Surface and Subsurface Soil

A maximum of 55 surface soil samples (0 to 1.0 bgs) and 10 subsurface soil samples (1.0 to 2.0 bgs) will be collected from the upland habitat at SWMU 2 from historical sampling points. Soil sampling locations will be identified by establishing four 10-foot by 10-foot sampling grids centered around each of the 11 historical sampling points: 9 historical surface soil sampling locations (2SB01, 2SB03, 2SB05, 2SS02, 2SS03, 2SS05, 2SS10, 2SS11, and 2SS14), 1 historical surface soil/subsurface soil sampling location (06SS103), and 1 historical subsurface soil sampling location (06SS101). All 11 of these sampling points have been sampled during previous field investigations [see Figure 5-4]). The concentrations of potential soil ecological risk drivers (i.e., antimony, copper, lead, mercury, and zinc) at these 11 sampling points span the range of concentrations detected in soil collected during previous investigations (see Tables 3-4 and 3-5).

At each historical sampling point, 5 surface soil samples will be collected (one from each of the four 10-foot by 10-foot sampling grids and one from the grid system's center point [approximate location of the historical sampling point]; total of 55). Subsurface soil samples also will be collected at two of the historical locations (0633103 and 06SS101; five per historical sampling point for a total of 10 subsurface soil samples). When subsurface soil samples are collected, they will be co-located with surface soil samples. The location sampled within each grid will be determined in the field and will be biased toward potential depositional areas (i.e., depressions/low points). In addition to the SWMU-specific surface soil samples, a maximum of six surface soil samples and six subsurface soil samples (co-located with surface soil) will be collected from one or more of the proposed upland reference areas identified on Figure 5-1. The criteria used to determine if a given reference area is appropriate were previously discussed in Section 5.2.

The SWMU 2 and reference area surface soil samples will be collected using dedicated stainless steel spoons or stainless steel hand augers. Specific sampling equipment used at a given sampling point will be dictated by the conditions encountered in the field (e.g., degree of soil compaction). Each sample will be homogenized in aluminum pans in the field and split between (1) a smaller portion submitted to the analytical laboratory for quick-turn (48-hour) antimony, copper, lead, mercury, and zinc (including associated QA/QC samples); and (2) a larger portion held in a sealed storage container on ice until results of the quick-turn analyses are available. Upon receipt of the analytical results, a maximum of 10 SWMU 2 soil samples and 3 reference area soil samples will be selected and submitted to the toxicity testing laboratory for 28-day *Eisenia fetida* survival, growth, and reproduction tests. A portion of each sample submitted for toxicity testing also will submitted to the analytical laboratory for TOC, pH, and grain size analyses. The SWMU 2 soil samples submitted for toxicity and analytical testing will come from the portions held on ice while waiting for quick-turn analytical results and will be selected to capture the gradient of antimony, copper, lead, mercury, and zinc concentrations measured in soil at the site. Determination of the capture of a suitable concentration gradient will be based on obtaining soil samples with concentrations ranging from below terrestrial invertebrate-based screening values (see Section 4.4) on the lower end to equaling or exceeding the 95 percent UCL of a combined surface and subsurface data set (i.e., combined data set consisting of surface and subsurface soil data used in Step 2 and Step 3a of the baseline ERA [Baker, 2006a]) on the upper end. 95 percent UCL values used in this determination will be derived using USEPA ProUCL Version 3.00.02 software.

The reference area soil samples submitted for toxicity testing also will come from the portions held on ice while waiting for quick-turn analytical results. A given reference area soil sample will be considered appropriate for toxicological testing if: (1) the antimony, copper, lead, mercury, and zinc concentration in that sample is less than the terrestrial invertebrate-based screening values identified in Section 4.4; and (2) the TOC concentration, pH, and grain size characteristics of that sample are similar to one or more of the SWMU 2 soil samples selected for toxicity testing. The range of TOC concentrations, pH values, and grain size characteristics encountered in the SWMU 2 soil samples selected for toxicity testing will dictate the actual number of reference samples submitted for *Eisenia fetida* toxicity testing. It is noted that if one or more SWMU 2 subsurface soil samples are selected for toxicity testing, the reference area samples submitted for toxicity testing will include at least one subsurface sample.

5.3.2.2 Estuarine Wetland Sediment and Fiddler Crab Tissue

A maximum of 24 estuarine wetland sediment samples will be collected at SWMU 2 using a systemic sampling scheme by establishing 25-foot by 25-foot sampling grids (see Figure 5-5) at locations that cover the range of copper, lead and zinc concentrations detected during previous investigations (see Figure 6-2). A single sediment sample will be collected from the center point of each grid. If a given sampling grid overlaps with upland habitat, the sediment sample from that grid will be collected from the center point of the grid portion located within estuarine wetland habitat. In addition to the SWMU-specific estuarine wetland sediment samples, a maximum of six sediment samples will be collected from the proposed estuarine wetland reference area identified on Figure 5-1. The criteria used to determine if the proposed reference area is appropriate were previously discussed in Section 5.2.

The SWMU 2 and reference area estuarine wetland sediment samples will be collected using dedicated stainless steel spoons. Each sample will be homogenized in aluminum pans in the field and split between (1) a smaller portion submitted to the analytical laboratory for quick-turn (48-hour) total copper, lead, mercury, and zinc analyses (including associated QA/QC samples; note that copper, lead, and zinc represent potential ecological risk drivers for benthic invertebrates, while lead and mercury represent potential ecological risk drivers for avian invertebrate consumers); and (2) a larger portion held in a sealed storage container on ice until results of the quick-turn analyses are available. Upon receipt of the analytical results, a maximum of 7 SWMU 2 sediment samples and 3 reference area sediment samples will be selected and submitted to the toxicity testing laboratory for 28-day *Leptocheirus plumulosus* survival, growth, and reproduction tests and 20-day *Neanthes arenaceodentata* survival and growth tests. A portion of each sample submitted for toxicity testing also will submitted to the analytical laboratory for ammonia, sulfide, pH, TOC, grain size, AVS, and SEM (cadmium, copper, lead, nickel, silver, and zinc) analyses. The SWMU 2 and reference area sediment samples submitted for toxicity and analytical testing will come from the portions held on ice while waiting for quick-turn analytical results and will be selected to capture the gradient of copper, lead and, zinc concentrations measured at the site. Determination of the capture of a suitable concentration gradient will be based on obtaining sediment samples with concentrations ranging from below invertebrate-based screening values (see Section 4.4) on the lower end to equaling or exceeding the 95 percent UCL of the existing dataset (i.e., dataset used in Step 2 and Step 3a of the baseline ERA [Baker, 2006a]) on the upper end. Ninety-five percent UCL values used in this determination will be derived using USEPA ProUCL Version 3.00.02 software. As discussed above, mercury is included as an estuarine wetland sediment analyte to address potential risks to avian invertebrate consumers. As such, estuarine wetland sediment samples submitted for toxicity testing will not be selected to capture the gradient of mercury concentrations measured at the site.

The reference area sediment samples submitted for toxicity testing also will come from the portions held on ice while waiting for quick-turn analytical results. A given reference area sediment sample will be considered appropriate for toxicological testing if: (1) the copper, lead, and zinc concentration in that sample is less than the invertebrate-based screening values identified in Section 4.4; and (2) the ammonia, sulfide, and TOC concentration, pH, and grain size characteristics of that sample are similar to one or more of the SWMU 2 sediment samples selected for toxicity testing. The range of ammonia, sulfide, and TOC concentrations, pH values, and grain size characteristics encountered in the SWMU 2 sediment samples selected for toxicity testing will dictate the actual number of reference sediment samples submitted for *Leptocheirus plumulosus* and *Neanthes arenaceodentata* toxicity testing.

In addition to the sediment samples discussed above, fiddler crab tissue samples will be collected from the estuarine wetland system downgradient from the upland portion of SWMU 2. The estuarine wetland coastline, between historical sample location 2EWS18 and 2EWS04, will be divided into four segments of approximate equal length based on linear feet of coastline (see Figure 5-6). These historical sampling locations (i.e., 2EWS18 and 2EWS04) form the southwestern and northeastern boundary of potentially impacted wetland sediments as determined by existing copper, lead, and zinc analytical data (see Figure 3-5). The segments also encompass the grid system that will be established for identification of sediment sample locations for analytical and toxicity testing. Two fiddler crab composite samples will be collected from each segment and analyzed for total lead and mercury, percent lipids, and percent moisture. Each composite sample will consist of six individual whole-body crabs (ingesta will not be purged). Fiddler crabs will be rinsed with laboratory-grade deionized water and frozen prior to shipment. Crab samples also will be packed with ice to ensure they remain frozen during shipment.

In addition to the SWMU-specific fiddler crab tissue sampling, a total of four fiddler crab tissue composite samples will be collected from the estuarine wetland reference area (in the vicinity of sediment sample locations for analytical and toxicity testing). Each composite sample will consist of six individual whole-body crabs (ingesta will not be purged). The reference area fiddler crab tissue samples will be prepared as described previously.

5.3.2.3 Seagrass Tissue and Open Water Sediment

A maximum of six composite turtle grass samples will be collected from three locations within the open water portion of SWMU 2 (one above ground plant composite sample and one whole-body-plant composite per sample location). Compositing of plant samples will be necessary to achieve the desired tissue mass (2 to 5 grams wet weight) for analysis. Above ground seagrass tissue will be collected by shearing plants at the sediment-water interface using a sharp blade. Whole-plant samples will be collected with a rake and/or shovel, depending on the depth of the water column and firmness of the sediment and rhizome layer. As discussed in Section 4.2, turtle grass will be targeted for tissue collection as it is the preferred manatee forage species and is the dominant species found within the open water portion of SWMU 2. Tissue samples will be rinsed in distilled water, wrapped in aluminum foil, placed in freezer bags, frozen in a freezer prior to shipment to the analytical laboratory, and packed with ice to remain frozen during shipment. Each above ground and whole-body tissue composite samples will be analyzed for total arsenic, cadmium, copper, lead, mercury, selenium, and zinc, as well as percent moisture.

A single surface sediment composite sample (0 to 6 inches bgs) will be collected at each seagrass sampling location immediately following seagrass collection activities using dedicated hand corers. Sediment from each location will be homogenized in aluminum pans and submitted to the analytical laboratory and analyzed for total arsenic, cadmium, copper, lead, mercury, selenium, and zinc, TOC, and grain size. Associated field QA/QC samples (i.e., field duplicates and MS/MSDs) also will be collected and analyzed for arsenic, cadmium, copper, lead, mercury, selenium, and zinc.

Because seagrass tissue and open water sediment samples will be collected from the open water reference areas identified in Figure 5-1 as part of the baseline ERA field sampling activities at SWMU 1, additional samples will not be collected during baseline ERA field sampling activities at SWMU 2. However, this approach will require that reference area samples (seagrass and sediment) collected during baseline ERA field sampling activities at SWMU 1 include analyses for lead (lead was identified as a potential ecological risk driver for West Indian manatee feed web exposures only at SWMU 2. All other potential ecological risk drivers are common to both SWMUs.

It is noted that arsenic, cadmium, copper, lead, mercury, selenium, and zinc concentrations detected in SWMU 2 open water sediment collected during previous investigations (Baker, 2006a) exhibit a fairly uniform concentration distribution throughout the open water portion of SWMU 2. As such, specific locations are not targeted for sampling based on analytical chemistry. Sample locations will be selected in field based on the presence of turtle grass.

5.4 Toxicity Testing

Direct toxicity to terrestrial invertebrates within the upland portions of SWMUs 1 and 2 will be evaluated using 28-day *Eisenia fetida* survival, growth, and reproduction tests, while direct toxicity to aquatic benthic invertebrates within the estuarine wetland portion of SWMU 2 will be evaluated using 28-day *Leptocheirus plumulosus* survival, growth, and reproduction tests and 20-day *Neanthes arenaceodentata* survival and growth tests. General endpoints for *Eisenia fetida* are survival, calculated as the percentage of earthworms at test initiation that survive at test termination; growth, calculated as the mean wet weight per earthworm at test termination; and reproduction, calculated as the number of cocoons per surviving earthworm. General test endpoints for *Leptocheirus plumulosus* are survival, calculated as the percentage of neonates at test initiation that survive as adults at test termination; growth rate, calculated as the mean dry weight per adult amphipod at test termination; and reproduction; calculated as the number of offspring per surviving adult. General test endpoints for *Neanthes arenaceodentata* are survival; calculated as the percentage of polychaetes at test initiation that survive at test termination; and growth, calculated as the mean dry weight per surviving polychaete at test termination. Specific calculations for each measurement endpoint will be specified in laboratory toxicity test SOPs, which will be provided to NAPR, Navy BRAC PMO SE, and USEPA once a toxicity laboratory is procured (prior to implementation of the FSAP).

Sediment samples will be overlain with water specified by the procured laboratory with water quality characteristics (e.g., salinity) similar to the water quality characteristics of surface water at the site (field measurements of temperature, salinity, dissolved oxygen, conductivity, pH, and total suspended solids will be collected from representative locations during the collection of sediment samples). A negative control will be run for each species to ensure that the populations of organisms used in the toxicity tests are healthy. The testing laboratory will determine the appropriate substrates for control testing. Good health is demonstrated when the organism's performance meets or exceeds the control performance acceptability criteria for survival, growth, and/or reproduction. The procured laboratory's SOPs will specify acceptable control performance criteria. For a given species, if control performance falls below the acceptability criteria, the results of the toxicity tests will be considered invalid and the tests will be rerun at the expense of the toxicity laboratory.

General criteria for the *Eisenia fetida* toxicity tests are outlined in *Standard Guide for Conducting Laboratory Soil Toxicity or Bioaccumulation Tests with the Lumbricid Earthworm Eisenia Fetida and the Enchytraeid Potworm Enchytraeus albidus* (ASTM, 2006). General criteria for the *Leptocheirus plumulosus* toxicity tests are outlined in *Methods for Assessing the Chronic Toxicity of Marine and Estuarine Sediment-Associated Contaminants with the Amphipod Leptocheirus plumulosus* (USEPA, 2001), while general criteria for the *Neanthes arenaceodentata* toxicity tests are outlined in *Standard Guide for Conducting Acute, Chronic, and Life-Cycle Aquatic Toxicity Tests with Polychaetous Annelids* (ASTM, 2000). However, these criteria may vary from those specified by the procured laboratory's SOP. Once a laboratory is procured, the laboratory's SOP will be provided to NAPR, Navy BRAC PMO SE, and USEPA for approval prior to implementation of field activities. The performance of organisms in SWMUs 1 and 2 soil and SWMU 2 estuarine wetland sediment will be statistically compared to that of organisms in the appropriate reference soil and sediment to determine if endpoint measurements (e.g., survival, growth, and/or reproduction) differ significantly using statistical tests outlined in the toxicity testing laboratory's SOPs.

5.5 Earthworm Bioaccumulation

Earthworms (*Eisenia fetida*) maintained in soil during toxicity testing (see Section 5.4) will be used to evaluate terrestrial avian omnivore food web exposures to potential ecological risk drivers in SWMUs 1 and 2 soil. For each SWMU, a maximum of 13 composite earthworm tissue samples will be submitted for analytical testing (10 SWMU-specific composite samples and 3 reference composite samples). One composite sample will be prepared for each sample tested for toxicity by combining all surviving earthworms from each replicate at test termination. Surviving earthworms will be transferred to vessels containing damp paper (e.g., filter paper) for depuration. After depuration, the worms will be transferred to sample containers, frozen, and submitted to the analytical laboratory for chemical analyses. The number of composite earthworm tissue samples submitted for analytical testing may vary depending on the actual number of soil samples evaluated for toxicity. To ensure that each soil sample will provide a viable tissue sample, a portion of the worms from each replicate will be removed after 14 days of exposure, depurated, and frozen in case significant mortality at the end of the longer exposure period prevents the collection of a sufficient biomass for analytical testing.

Tissue samples from earthworms maintained in SWMU 1 soil during toxicity testing, as well as associated tissue samples maintained in reference soil during toxicity testing will be analyzed for cadmium, lead, mercury, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'DDT. These chemicals represent the potential ecological risk drivers identified in Step 3a of the ERA process for SWMU 1 avian omnivore food web exposures). Tissue samples from earthworms maintained in SWMU 2 soil and associated reference soil during toxicity testing will be analyzed for copper, lead, mercury, and zinc (potential ecological risk drivers for SWMU 2 avian omnivore food web exposures). In addition, to the parameters listed above, earthworm tissue composite samples will be analyzed for percent moisture and percent lipids.

5.6 Uncertainties

As at any field site, there is local variability in the sediment's physical/chemical properties. Because these factors can influence toxicity test results, it is often difficult to discern the cause of biological responses in laboratory toxicity tests. To determine if these factors are influencing test results, SWMU-specific soil and reference area soil samples submitted for *Eisenia fetida* toxicity testing will be analyzed for TOC, pH, and grain size distribution, while SWMU-specific sediment and reference area sediment submitted for *Leptocheirus plumulosus* and *Neanthes arenaceodentata* toxicity testing will be analyzed for AVS/SEM, ammonia, sulfide, TOC, pH, and grain size distribution. These data will be reviewed to determine whether there are any correlations between their concentration/distribution in soil/sediment and test organism response (see Section 4.4).

The assessment endpoints identified in Section 3.3 do not include all possible lower trophic level aquatic receptors potentially at risk. For example, the conceptual models indicate that potentially complete exposure pathways for plants are present; however, plants were not selected as an assessment endpoint for this baseline ERA. The decision to exclude terrestrial plants from further evaluation is based upon observations recorded during a qualitative habitat characterization conducted at each SWMU (see Section 3.3 and Appendix C). Because all potential impacts on the upland vegetative communities cannot be quantified by visual inspections alone, the decision to exclude terrestrial plants from further evaluation in the baseline ERA represents a source of uncertainty.

The SWMUs 1 and 2 assessment endpoints identified in Section 3.3 do not include all possible upper trophic level terrestrial receptors potentially at risk (i.e., terrestrial avian herbivores). However, the terrestrial avian receptor selected as an assessment endpoint in this baseline ERA (American robin) is representative of those potential receptors at greatest risk from exposures to contaminants in soil. This conclusion is based on refined screening-level risk estimates derived in Step 3a of the Navy ERA process (see Baker, 2006a). For this reason, any necessary risk management decisions based on the American robin will likely be protective of all avian receptors excluded from evaluation, including terrestrial avian herbivores.

5.7 Quality Assurance/Quality Control Samples

The QA/QC requirements for samples collected during the baseline ERA field investigation are presented in the Master DCQAP (Baker, 1995). As presented in Tables 5-1, 5-2, and 5-3, the following QA/QC samples will be collected during field sampling activities to (1) ensure dedicated sampling equipment are not contaminated (equipment rinsate blanks); (2) establish field background conditions (field blanks); (3) evaluate field methodologies (duplicate samples); and (4) evaluate the laboratory process (MS/MSDs).

Equipment Rinsate Blanks - Equipment rinsate blanks are defined as samples that are obtained by running analyte-free water over/through sample collection equipment before its first use (new or dedicated sampling equipment). The following equipment rinsate blanks are anticipated. Note that the actual equipment rinsate blanks collected will depend on the specific equipment used to collect the samples discussed in Sections 5.2 (verification of field sampling design), 5.3.1 (SWMU 1 baseline ERA field investigation), and 5.3.2 (SWMU 2 baseline ERA field investigation).

Verification of Field Sampling Design:

- One equipment rinsate blank will be collected from a stainless steel spoon used to sample surface and subsurface soil and estuarine wetland sediment at the upland and estuarine wetland reference areas. The rinsate will be analyzed for total antimony, cadmium, copper, lead, mercury, tin, and zinc, and for 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

- One equipment rinsate blank will be collected from a stainless steel hand auger used to sample surface and subsurface soil at the upland reference areas. The rinsate will be analyzed for total antimony, cadmium, copper, lead, mercury, tin, and zinc, and for 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

SWMU 1 Baseline Ecological Risk Assessment Field Investigation:

- One equipment rinsate blank will be collected from a stainless steel spoon used to sample surface soil at SWMU 1 and the upland reference areas. The rinsate will be analyzed for total antimony, cadmium, copper, lead, mercury, tin, and zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

- One equipment rinsate blank will be collected from a stainless steel hand auger used to sample surface soil at SWMU 1 and the upland reference area. The rinsate will be analyzed for total antimony, cadmium, copper, lead, mercury, tin, and zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

- One equipment rinsate blank will be collected from a disposable hand corer used to sample open water sediment at SWMU 1 and the open water reference areas. The rinsate will be analyzed for total arsenic, cadmium, copper, lead, mercury, selenium, and zinc. As open water reference sediment will not be collected from the reference area during baseline ERA field sampling activities at SWMU 2, the parameter list for this rinsate includes those potential ecological risk drivers unique to SWMU 2 open water sediment (i.e., lead).

- One equipment rinsate blank will be collected from an aluminum pan used to homogenize open water sediment samples collected at SWMU 1 and the open water reference areas. The rinsate will be analyzed for total arsenic, cadmium, copper, lead, mercury, selenium, and zinc. As open water reference sediment will not be collected from the reference area during baseline ERA field sampling activities at SWMU 2, the parameter list for this rinsate includes those potential ecological risk drivers unique to SWMU 2 open water sediment (i.e., lead).

SWMU 2 Baseline Ecological Risk Assessment Field Investigation:

- One equipment rinsate blank will be collected from a stainless steel spoon used to sample surface and subsurface soil and estuarine wetland sediment at SWMU 2 and the upland and estuarine wetland reference areas. The rinsate will be analyzed for total antimony, copper, lead, mercury, and zinc.

- One equipment rinsate blank will be collected from a stainless steel hand auger used to sample surface and/or subsurface soil at SWMU 2 and the upland reference area. The rinsate will be analyzed for total antimony, copper, lead, mercury, and zinc.

- One equipment rinsate blank will be collected from a hand corer used to sample estuarine wetland sediment at SWMU 2 and the reference area. The rinsate will be analyzed for total copper, lead, and zinc.

- One equipment rinsate blank will be collected from an aluminum pan used to homogenize open water sediment samples collected at SWMU 2. The rinsate will be analyzed for total arsenic, cadmium, copper, lead, mercury, selenium, and zinc.

The results from the equipment rinsates will be used to evaluate the dedicated sampling equipment. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples.

Field Blanks - Field blanks are defined as samples that are obtained by pouring analyte-free water (e.g., laboratory distilled water) into appropriate sample containers at pre-designated field locations. This is done to determine if any contaminants present in the area may have an effect on sample integrity. Field blanks should not be collected in dusty environments and/or from areas where contamination is present in the atmosphere and originating from a source other than the source being sampled. One field blank will be collected during the field verification of the baseline ERA study design (analyzed for arsenic, antimony, cadmium, copper, lead, mercury, selenium, tin, and zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT), one field blank will be collected during the baseline ERA field sampling activities at SWMU 1 (analyzed for arsenic, antimony, cadmium, copper, lead, mercury, selenium, tin, and zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT), and one field blank will be collected during the baseline ERA field sampling activities at SWMU 2 (analyzed for total arsenic, antimony, copper, lead, mercury, selenium, and zinc).

Field Duplicates - Field duplicate samples are collected concurrently with environmental samples. All samples are split. Field duplicates will be collected at a frequency of 10 percent (1/10).

MS/MSDs - MS/MSD samples are collected to evaluate the matrix effect of the sample upon the analytical methodology and the laboratory process through a comparison of MS and MSD analytical results. MS/MSDs will be collected at a frequency of 5 percent (1/20).

5.8 Sample Designations

In order to identify and accurately track the surface and subsurface soil samples, estuarine wetland sediment samples, open water sediment samples, fiddler crab tissue samples, and seagrass tissue samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the SWMU, the sample media, sampling location, the investigation, and QA/QC qualifiers. The sample designation format is as follows:

[Site #]-[Investigation]-[Media][Station #][QA/QC]

An explanation of each of these identifiers is given below.

SWMU #: SWMU 1
SWMU 2

Investigation: Samples collected during verification of the field sampling design will be indicated by "V", while samples collected during the baseline ERA field investigation will be indicated by "B".

Media:
ER = Equipment Rinsate
FB = Field Blank
SS = Surface Soil
SB = Subsurface Soil
EWSD = Estuarine Wetland Sediment Sample
OWSD = Open Water Sediment Sample
E = Earthworm Tissue Sample
FC = Fiddler Crab Tissue Sample

SG = Seagrass Tissue Sample

Station #: For a given medium, each sample will be identified with a unique identification number (starting with 01). Seagrass tissue sample identification numbers also will include a "-AG" extension to indicate collection of the above ground portion of the plant or "-WP" extension to indicate collection of the whole plant.

QA/QC: (D) = Duplicate Sample
(MS/MSD) = Matrix Spike/Matrix Spike Duplicate

Under this sample designation format the sample number 2B-OWSD01D refers to:

1B-OWSD01D	SWMU 1
1B-OWSD01D	Baseline ERA
1B-OWSD01D	Open Water Sediment Sample
1B-OWSD01D	Sample Location 01
1B-OWSD01D	Duplicate (QA/QC) Sample

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

5.9 Investigation Derived Waste

Investigative Derived Waste (IDW) management will be conducted in accordance with guidance from USEPA's Guide to Management of Investigation-Derived Wastes (USEPA, 1992). The document states, "*most IDW (with the exception of non-indigenous IDW) generated during the course of the investigation are intrinsic elements of the site, and should be managed with other wastes from the site, consistent with final remedy.*" IDW generated during the field investigation will only include miscellaneous items such as gloves and used personal protective equipment (PPE). No decontamination fluid IDW will be generated due to the use of dedicated sampling equipment. Sediment cuttings from the sampling activities will be returned to the areas sampled. Items of PPE that have come in contact with potentially contaminated materials, such as disposable gloves and Tyvek®, as well as dedicated sampling equipment, will be placed in garbage bags and disposed of in trash dump boxes.

As stated, the use of dedicated equipment or materials negates the requirement of decontamination of any equipment or materials. As such, no IDW sampling or analysis will be required.

5.10 Sample Analysis, Data Validation, and Data Evaluation

All analyses will be conducted at a contracted laboratory that fulfills all requirements of the Navy's QA/QC Program Manual and USEPA's Contract Laboratory Program (CLP). All contaminant analytical data (total arsenic, antimony, cadmium, copper, lead, mercury, selenium, tin, and zinc, and 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, AVS, and SEM) generated by this investigation will be subjected to independent, third party validation in accordance with the USEPA Region III Data Validation Operating Procedures. Analytical data related to physiochemical properties of sediment and laboratory toxicity test conditions (ammonia, sulfide, TOC, pH, and grain size) will not be validated. The Master DCQAP establishes all the general QA requirements for the analyses that will occur during the investigation (Baker, 1995). The Master DCQAP presents the specific policies, organization, functions, and QA/QC activities associated with the analytical data, and in conjunction with data validation, is designed to ensure that acceptable data requirements and error levels are achieved. A summary of the samples that will be collected as part of the verification of the field sampling design is presented in Table 5-1. Samples that will be collected as part of the SWMUs 1 and 2 baseline ERA field investigations are summarized in Tables 5-2 and 5-3, respectively. Analytical methods and analytical data quality levels are summarized in Table 5-4, while Table 5-5 presents method performance limits for each contaminant.

5.11 Data Management/Geographical Information System

Data management activities will include the establishment of sample tracking forms and activities from sample collection to independent, third party data validation. Activities include the systematic assignment of alphanumeric sample identifiers to each sample location for use in the relational database and the production of sample tracking spreadsheets. Coordination with field personnel during field sampling activities, the laboratory project manager, and the data validation subcontractor will also be included. This also includes management of laboratory data and conversion of the analytical data into tables that will be included in the individual reports.

Geographic coordinates of the SWMUs 1 and 2 and reference area sample locations will be collected using a Global Positioning System (GPS) during the field event. Coordinates of some permanent or significant structures in the vicinity of each location may also be collected to identify approximate boundaries, if required. All GPS coordinate points will be correlated to the Puerto Rico State Plane Coordinate System.

Mapping data and analytical data will be compiled for use in a Geographical Information System (GIS) and other data management processes. When the field investigation and laboratory analysis are complete, Baker personnel will review all laboratory data and the results from the independent data validation subcontractor. Data and all appropriate validation qualifiers will be added to the database containing the laboratory data. Ultimately, these data will be exported to the GIS for mapping, presentation, and archival purposes.

5.12 Project Reporting

The analytical and toxicity test data will be evaluated and presented in Step 7 draft baseline ERA reports (separate reports for SWMUs 1 and 2). The SWMU 1 report will evaluate the potential risk of terrestrial invertebrate exposures to antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in surface soil, terrestrial avian omnivore food web exposures to cadmium, lead, mercury, zinc, 4,4'-DDD, 4.4'-DDE, and 4,4'-DDT in surface soil, and West Indian manatee food web exposures to arsenic, cadmium, copper, mercury, selenium, and zinc in open water sediment (see section 4.4):

- Comparison of antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT concentrations in SWMU 1 surface soil to appropriate literature-based toxicological thresholds.

- Comparison of *Eisenia fetida* survival, growth, and reproduction in SWMU 1 surface soil to *Eisenia fetida* survival, growth, and reproduction in reference surface soil.

- Existence of patterns in laboratory toxicity tests results with chemical burden and other chemical/physical characteristics of the soils.

- Comparison of terrestrial avian omnivore (i.e., American robin) and West Indian manatee dietary intakes to ingestion-based NOAELs/LOAELs.

The SWMU 2 report will evaluate the potential risk of terrestrial invertebrate exposures to antimony, copper, lead, mercury, and zinc in soil, terrestrial avian omnivore food web exposures to copper, lead, mercury, and zinc in soil, aquatic invertebrate exposures to copper, lead, and zinc in estuarine wetland sediment, aquatic avian invertebrate consumer exposures to lead and mercury in estuarine wetland sediment, and West Indian manatee food web exposures to arsenic, cadmium, copper, lead, mercury, selenium and zinc in open water sediment:

- Comparison of antimony, copper, lead, mercury, and zinc in SWMU 2 soil concentrations to appropriate literature-based toxicological thresholds.

- Comparison of *Eisenia fetida* survival, growth, and reproduction in SWMU 2 soil to *Eisenia fetida* survival, growth, and reproduction in reference surface soil.

- Comparison of copper, lead, and zinc concentrations in SWMU 2 estuarine wetland sediment to appropriate literature-based toxicological thresholds.

- Derivation of AVS-SEM ratios to assess the bioavailability of bulk copper, lead, and zinc concentrations in SWMU 2 estuarine wetland sediment.

- Comparison of *Leptocheirus plumulosus* survival, growth, and reproduction and *Neanthes arenaceodentata* survival and growth in SWMU 2 estuarine wetland sediment to *Leptocheirus plumulosus* survival, growth, and reproduction and *Neanthes arenaceodentata* survival and growth in reference estuarine wetland sediment.

- Existence of patterns in laboratory toxicity tests results with chemical burden and other chemical/physical characteristics of the soils/sediments.

- Comparison of terrestrial avian omnivore (i.e., American robin), aquatic avian invertebrate consumer (spotted sandpiper), and West Indian manatee dietary intakes to ingestion-based NOAELs/LOAELs.

These lines of evidence will be evaluated in Step 7 using a weight-of-evidence approach (see Section 4.4). The methods, results, analyses, and risk characterization conclusions for each baseline ERA will be reported in a draft and final baseline ERA report. For a given SWMU, if significant conflicts among these lines of evidence result in uncertain risk conclusions, additional data collection and evaluation beyond the proposed Step 4 sampling (see Section 4.0) might be required to resolve the uncertainties. Chemical-specific PRGs, if needed, will be calculated to aid the risk-management decision-making process. The decision to calculate PRGs will be based upon the results of the Step 7 baseline ERA (i.e., conclusion of unacceptable risk). The rational, methods, and calculations will be documented in a Step 8 technical memorandum.

6.0 PROJECT SCHEDULE

The schedule of events included in this Work Plan is depicted on Figure 6-1. It should be noted that this schedule is dependent upon USEPA review time. Many other factors may also extend the schedule such as resampling if additional sampling is required, weather delays in the field, if funding is delayed by the Navy, and consensus cannot be reached on how the USEPA's comments are incorporated.

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TABLES

TABLE 1-1
SUMMARY OF POTENTIAL ECOLOGICAL RISK DRIVERS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Terrestrial Habitat				Estuarine Wetland Aquatic Habitat			Open Water Aquatic Habitat (Ensenada Honda)		
	Invertebrate and Plant Communities		Upper Trophic Level Food Web Exposures		Invertebrate, Plant, and Fish Communities		Upper Trophic Level Food Web Exposures	Invertebrate, Plant, and Fish Communities		Upper Trophic Level Food Web Exposures
SWMU	Surface Soil	Subsurface Soil	Surface Soil	Subsurface Soil	Surface Water	Sediment		Surface Water	Sediment	
SWMU 1	Antimony Cadmium Copper Lead Mercury Tin Zinc 4,4'-DDD 4,4'-DDE 4,4'-DDT	4,4'-DDT 4,4'-DDE	Cadmium Lead Mercury Zinc 4,4'-DDD 4,4'-DDE 4,4'-DDT	None	None	None	None	None	None	Arsenic Cadmium Copper Mercury Selenium Zinc
SWMU 2	Antimony Copper Lead Mercury Zinc	Antimony Copper Lead Mercury Zinc	Lead Mercury Zinc	Copper Lead Zinc	None	Copper Lead Zinc	Lead Mercury	None	None	Arsenic Cadmium Copper Lead Mercury Selenium Zinc

Notes:

SWMU = Solid Waste Management Unit

TABLE 2-1

LIST OF BIRDS REPORTED FROM NAVAL ACTIVITY PUERTO RICO
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Common Name (1)		
Pied-billed grebe	Red-billed tropicbird	Brown pelican (2)
Brown booby	Magnificent frigatebird	Great blue heron
Louisiana heron	Snowy egret	Great egret
Striated heron	Little blue heron	Cattle egret
Least bittern	Yellow-crowned night heron	Black-crowned night heron
White-cheeked pintail	Blue-winged teal	American widgeon
Red-tailed hawk	Osprey	Merlin
Clapper rail	American coot	Caribbean coot
Common gallinule	Piping plover (3)	Semipalmated plover
Black-bellied plover	Wilson's plover	Killdeer
Ruddy turnstone	Black-necked stilt	Whimbrel
Spotted sandpiper	Semipalmated sandpiper	Short-billed dowitcher
Greater yellowlegs	Lesser yellowlegs	Willet
Stilt sandpiper	Pectoral sandpiper	Laughing gull
Royal tern	Sandwich tern	Bridled tern
Least tern	Brown noddy	White-winged dove
Zenaida dove	White-crowned pigeon	Mourning dove
Red-necked pigeon	Common ground dove	Bridled quail dove
Ruddy quail dove	Caribbean parakeet	Smooth-billed ani
Yellow-billed cuckoo	Mangrove cockoo	Short-eared owl
Chuck-will's-widow	Common nighthawk	Antillean crested hummingbird
Green-throated carib	Antillean mango	Belted kingfisher

TABLE 2-1

LIST OF BIRDS REPORTED FROM NAVAL ACTIVITY PUERTO RICO
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO

Common Name [1]		
Gray kingbird	Loggerhead kingbird	Stolid flycatcher
Caribbean elaenia	Purple martin	Cave swallow
Barn swallow	Northern mockingbird	Pearly-eyed thrasher
Red-legged thrush	Black-whiskered vireo	American redstart
Parula warbler	Prairie warbler	Yellow warbler
Magnolia warbler	Cape May warbler	Black-throated blue warbler
Adelaide's warbler	Palm warbler	Black and white warbler
Ovenbird	Northern water thrush	Bananaquit
Striped-headed tanager	Shiny cowbird	Black-cowled oriole
Greater Antillean grackle	Yellow-shouldered blackbird [2]	Hooded mannikin
Yellow-faced grassquit	Black-faced grassquit	Least sandpiper
Western sandpiper	Puerto Rican woodpecker	Rock dove
Puerto Rican emerald	Puerto Rican flycatcher	Pin-tailed whydah
Spice finch	Ruddy duck	Peregrine falcon
Marbled godwit	Puerto Rican lizard cuckoo	Prothonotary warbler
Green-winged teal	Orange-cheeked waxbill	Roseate tern [3][4]
Least grebe	West Indian whistling duck	Puerto Rican screech owl
Puerto Rican tody		

Notes:

[1] List of birds taken from Geo-Marine, Inc. (1998).
[2] Federally-designated endangered species.
[3] Federally-designated threatened species.
[4] Species has the potential to occur at Naval Activity Puerto Rico.

TABLE 3-1

SUMMARY OF ANALYTICAL RESULTS: SURFACE SOIL
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	1MW01	1MW02	1MW03	1MW04	1SB01	1SB02	1SB03	1SS01	1SS02
Sample ID	1MW01-00	1MW02-00	1MW03-00	1MW04-00	1SB01-00	1SB02-00	1SB03-00	1SS01	1SS02
Sample Date	10/29/96	10/11/96	10/11/96	10/13/96	10/13/96	10/13/96	10/11/96	10/13/96	10/11/96
Depth Range (ft.)	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00
Organochlorine Pesticides (ug/kg)									
4,4'-DDD	9 U	9.6 U	9.8 U	9.4 U	10 U	9.7 U	20 U	9.1 U	9.6 U
4,4'-DDE	9 U	9.6 U	4.1	7.4	1.2 J	9.7 U	610	9.1 U	3.2
4,4'-DDT	9 U	9.6 U	4.5	14	2.5	1.2 J	340	9.1 U	1.6 J
Inorganics, Total (mg/kg)									
Antimony	2.4 J	2.8 J	1.9 UJ	2.1 J	2.9 J	1.5 J	1.9 J	1.3 UJ	2 J
Cadmium	0.77	0.27	0.34	0.41	0.23 U	0.38	0.7	0.2	0.56
Copper	169	19.8	45.9	71.2	41.5	75	57.1	35.2	45.9
Lead	3.6 R	4.4	13	8.3	5.4	7.5	25.7	3.4	5.9
Mercury	0.02 U	0.05	0.06	0.03	0.07	0.06	0.06	0.08	0.06
Tin	0.94 U	1 U	1.1	0.92 U	0.96 U	0.79 U	1.5	0.69 U	1.2
Zinc	140 J	13.9 J	38.3 J	40.9	28.3	35.8	61.6 J	19.1	26.9 J

TABLE 3-1

SUMMARY OF ANALYTICAL RESULTS: SURFACE SOIL
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	1SS03	1SS04	1SS05	1SS06	1SS07	1SS08	1SD01	1SD02	1SD03
Sample ID	1SS03	1SS04	1SS05	1SS06	1SS07	1SS08	1SD01	1SD02	1SD03
Sample Date	10/10/96	10/10/96	10/11/96	10/11/96	10/13/96	10/21/96	10/22/96	10/22/96	11/10/96
Depth Range (ft.)	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-0.00	0.00-0.00	0.00-0.00
Organochlorine Pesticides (ug/kg)									
4,4'-DDD	9.1 U	10 U	9.6 U	49 U	8.8 U	9 U	42	97	9.9 U
4,4'-DDE	9.1 U	1.7 J	1.6 J	1,300	280	9 U	930	370	9.9 U
4,4'-DDT	9.1 U	1.2 J	3.6	270	140	9 U	130	63	9.9 U
Inorganics, Total (mg/kg)									
Antimony	1.8 UJ	3.3 J	2.1 J	4 J	9.4 J	1.4 UJ	23.6 J	14.5 J	1.4 UJ
Cadmium	0.23 U	0.41	0.23 U	0.25 U	83.8	0.19 U	4.7	2.4	0.34
Copper	37.9	78.2	66.6	359	166	29.8	1020	608	50.8
Lead	2	9.3	9.1	79.4	101	6.9 J	659 J	966 J	1.3 J
Mercury	0.02 U	0.06	0.05	0.09	0.09	0.11	0.85	0.2	0.03 U
Tin	0.95 U	0.8 U	0.94 U	6.7	15.9	0.78 U	181	33.9	0.74 U
Zinc	23.1 J	29 J	36.9 J	136 J	223	24.8	1780	1100	15.6

TABLE 3-1

SUMMARY OF ANALYTICAL RESULTS: SURFACE SOIL
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	1SS09	1SS10	1SS11	1SS12	1SS13	1SS14	1SS15	1SS16	1SS17	1SS18	1SS19
Sample ID	1SS09	1SS10	1SS11	1SS12	1SS13	1SS14	1SS15	1SS16	1SS17	1SS18	1SS19
Sample Date	10/02/04	10/02/04	10/02/04	10/02/04	10/02/04	10/02/04	10/03/04	10/03/04	10/03/04	10/03/04	10/02/04
Depth Range (ft.)	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00
Organochlorine Pesticides (ug/kg)											
4,4'-DDD	9.6 J	220	15 J	NA	69 J	4.1 U	3.9 J	13,000	1.8 J	0.9 J	1.7 J
4,4'-DDE	110	810	89	NA	1,700	4.1 U	64	28,000	6.3	5.9	15
4,4'-DDT	95	110 J	61 J	NA	520 J	4.1 U	21 J	43,000 J	1.4 J	9.9	23
Inorganics, Total (mg/kg)											
Antimony	0.98 J	23 J	2.3 J	0.089 J	20 J	0.079 J	NA	NA	NA	NA	NA
Cadmium	0.33 J	5.1	9.4	0.12 J	12	0.082 J	NA	NA	NA	NA	NA
Copper	98 J	540 J	220 J	41 J	740 J	40 J	NA	NA	NA	NA	NA
Lead	34 J	680 J	94 J	4.2 J	660 J	8.7 J	NA	NA	NA	NA	NA
Mercury	0.064	0.44	0.15	0.075	0.59	0.034	NA	NA	NA	NA	NA
Tin	5.2 J	100	38	3 J	88	3.1 J	NA	NA	NA	NA	NA
Zinc	110 J	1,600 J	190 J	43 J	2,000 J	39 J	NA	NA	NA	NA	NA

TABLE 3-2

SUMMARY OF ANALYTICAL RESULTS: SUBSURFACE SOIL
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	05SS101	05SS102	05SS103	05SS104	05SS105	05SS106	1SS15	1SS16	1SS17
Sample ID	05SS126	05SS128	05SS130	05SS132	05SS135	05SS138	1SB15-01	1SB16-01	1SB17-01
Sample Date	11/15/92	11/15/92	11/15/92	11/16/92	11/16/92	11/17/92	10/02/04	10/02/04	10/02/04
Depth Range (ft bgs)	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	1.00 - 2.00	1.00 - 2.00	1.00 - 2.00
Organochlorine Pesticides (ug/kg)									
4,4'-DDE	5.5	2.2 J	480 J	0.63 J	4 U	3.7 U	4.2 U	520	11
4,4'-DDT	2.1 J	2.9 J	3,500 CD	0.49 J	4 U	0.11 NJ	4.2 U	960 J	10

TABLE 3-3

SUMMARY OF SEDIMENT ANALYTICAL RESULTS (INORGANICS): OPEN WATER HABITAT
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	1OW01	1OW02	1OW03	1OW04	1OW05	1OW06	1OW07	1OW08	1OW09
Sample ID	01OWSD01	01OWSD02	01OWSD03	01OWSD04	01OWSD05	01OWSD06	01OWSD07	01OWSD08	01OWSD09
Sample Date	07/24/03	07/24/03	07/25/03	07/25/03	07/25/03	07/24/03	07/24/03	07/25/03	07/25/03
Sample Depth (ft bgs)	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5
Inorganics (mg/kg)									
Arsenic	8.3	6.7	8.7	6.5	5.3	6.2	5.8	8.5	5.3
Cadmium	1.3 U	1.2 U	0.15 J	2.1 U	0.1 J	1.2 U	1.4 U	0.91 U	1.8 U
Copper	14	12	26	21	23	13	19	21	26
Mercury	0.034 J	0.029 J	0.062 J	0.085 U	0.066	0.032 J	0.024 J	0.023 J	0.031 J
Selenium	0.61 J	0.77 J	1.1 J	1.2 J	0.74 J	0.53 J	0.6 J	0.75 J	1 J
Zinc	18	16	32	25	32	17	27	13	30

TABLE 3-4

SUMMARY OF ANALYTICAL DATA: SURFACE SOIL
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	06SS103	2MW01	2MW02	2MW03	2SB01	2SB02	2SB03	2SB04	2SB05	2SD01	2SD02	2SD03
Sample ID	06SS145	2MW01-00	2MW02-00	2MW03-00	2SB01-00	2SB02-00	2SB03-00	2SB04-00	2SB05-00	2SD01	2SD02	2SD03
Sample Date	11/17/92	10/08/96	10/08/96	10/08/96	10/08/96	10/08/96	10/08/96	10/08/96	10/08/96	11/11/96	11/11/96	11/11/96
Sample Depth (ft bgs)	0.0-0.50	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00
Total Inorganics (mg/kg)												
Antimony	20.1 J	1.7 UJ	1.9 J	1.5 UJ	1.5 UJ	1.6 UJ	13.3 J	1.6 UJ	2.4 J	1.7 UJ	4.8 J	3.3 J
Copper	739	55.1 J	110 J	109 J	54.7 J	73.6 J	374 J	180 J	919 J	16.9	399	62.4
Lead	4,760 J	11.6	13	60.6	16.1	35.2	1,000	156	512	4	390 J	49.7 J
Mercury	0.45	0.05 J	0.04 J	0.07 J	0.07 J	0.16 J	0.33 J	0.09 J	0.37 J	0.04	0.14	0.05
Zinc	1,440	52	107	108	62	96.3	845	231	1,260	15.1	841	92.8

TABLE 3-4

SUMMARY OF ANALYTICAL DATA: SURFACE SOIL
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	2SS01	2SS02	2SS03	2SS04	2SS05	2SS07	2SS09	2SS10	2SS11	2SS12	2SS13	2SS14
Sample ID	2SS01	2SS02	2SS03	2SS04	2SS05	2SS07	2SS09	2SS10	2SS11	2SS12	2SS13	2SS14
Sample Date	10/05/04	10/05/04	10/05/04	10/05/04	10/05/04	10/05/04	10/04/04	10/04/04	10/04/04	10/04/04	10/04/04	10/04/04
Sample Depth (ft bgs)	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00	0.00 - 1.00
Total Inorganics (mg/kg)												
Antimony	0.98 J	0.41 J	24 J	0.18 J	2.8 J	0.77 J	0.34 J	0.47 J	0.97 J	0.23 J	0.19 J	0.11
Copper	190	110	270	76	880	150	640	120	190	130	160	83
Lead	77	59	1,400	31	280	90	140	330	360	61	44	22
Mercury	0.18 J	0.045 J	0.23 J	0.11 J	0.15 J	0.59 J	0.13 J	0.096 J	19 J	0.57 J	0.088 J	0.11
Zinc	520	130	720	95	800	150	460	1,000	350	290	150	75

TABLE 3-5

SUMMARY OF ANALYTICAL RESULTS: SUBSURFACE SOIL
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	06SS101	06SS102	06SS103	06SS104	06SS105	06SS106	06SS108	2SS01	2SS02	2SS03	2SS05	2SS07
Sample ID	06SS141	06SS143	06SS146	06SS147	06SS150	06SS153	06SS155D	2SS01-01	2SS02-01	2SS03-01	2SS05-01	2SS07-01
Sample Date	11/17/92	11/17/92	11/17/1992	11/17/92	11/17/92	11/17/92	11/17/92	10/05/04	10/05/04	10/05/04	10/05/04	10/05/04
Depth Range (ft bgs)	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.5	0.5-1.67	1.00 - 2.00	1.00 - 2.00	1.00 - 2.00	1.00 - 2.00	1.00 - 2.00
Total Inorganics (mg/kg)												
Antimony	17.9 J	6.3 J	19.8 J	2.4 UJ	4 UJ	2.6 UJ	3 J	0.27 J	0.32 J	4.7 J	1.7 J	0.26 J
Copper	5,850	227	774	4.3 B	136	77.8	54.5	180	93	280	390	130
Lead	1,210 J	130 J	5,850 J	3.1	7.5	77.4	5.6	110	54	470	190	56
Mercury	0.15 U	0.15 U	0.68	0.12 U	0.16 U	0.12 U	0.13 U	0.11 J	0.028 J	0.16 J	0.14 J	0.26 J
Zinc	3,350	200	2010	8.3	89.2	206	40.7	270	160	780	660	130

TABLE 3-6

SUMMARY OF SEDIMENT ANALYTICAL RESULTS (INORGANICS): ESTUARINE WETLAND HABITAT
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	2EWS01	2EWS02	2EWS03	2EWS04	2EWS05	2EWS06	2EWS07	2EWS08	2EWS09
Sample ID	02EWSSD01	02EWSSD02	02EWSSD03	02EWSSD04	02EWSSD05	02EWSSD06	02EWSSD07	02EWSSD08	02EWSSD09
Sample Date	07/27/03	07/27/03	07/27/03	07/27/03	07/27/03	07/27/03	07/27/03	07/27/03	07/27/03
Sample Depth (ft bgs)	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5
Inorganics (mg/kg)									
Copper	180	65	78	20	11	69	20	14	14
Lead	68	28	12	3.7	2.2	23	4	2.7	2.4
Mercury	0.27	0.22	0.083	0.022 J	0.027 J	0.21	0.028 J	0.015 J	0.022 J
Zinc	110	110	70	21	13	66	18	16	14

TABLE 3-7

SUMMARY OF SEDIMENT ANALYTICAL RESULTS (INORGANICS): OPEN WATER HABITAT
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL STATION ROOSEVELT ROADS, CEIBA, PUERTO RICO

Site ID	2OW01	2OW02	2OW03	2OW04	2OW05	2OW06	2OW07	2OW08	2OW09
Sample ID	02OWSD01	02OWSD02	02OWSD03	02OWSD04	02OWSD05	02OWSD06	02OWSD07	02OWSD08	02OWSD09
Sample Date	07/27/03	07/27/03	07/28/03	07/28/03	07/28/03	07/27/03	07/27/03	07/28/03	07/28/03
Sample Depth (ft bgs)	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5	0.0 - 0.5
Inorganics (mg/kg)									
Arsenic	8.6	9.2	9.3	10	6.8	6.1	11	7.9	3.5
Cadmium	0.99 U	1.5 U	1.2 U	0.88 U	1 U	0.93 U	0.091 J	0.95 U	1.2 U
Copper	15	16	19	8	13	11	13	16	10
Lead	3.4	3.7	4.6	48	2.1	2.6	4.5	3.6	2.1
Mercury	0.033 J	0.025 J	0.034	0.016 J	0.03 J	0.0094 J	0.047 U	0.027 J	0.018 J
Selenium	0.29 J	0.42 J	0.43 J	0.38 J	0.51 J	0.3 J	0.33 J	0.36 J	0.27 J
Zinc	19	25	29	12	15	19	23	18	21

TABLE 4-1
EXPOSURE PARAMETERS FOR UPPER TROPHIC LEVEL RECEPTORS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Receptor	Habitat	Body Weight (kg)		Food Ingestion Rate (kg/day - dry)		Area Use Factor
		Value	Reference	Value	Reference	
Birds:						
American robin	Terrestrial	0.0773	USEPA, 1993	0.00383	Levey and Karasov, 1989	1.00
Spotted sandpiper	Aquatic (estuarine wetland)	0.0404	Dunning, 1993	0.00804	Allometric equation from Nagy, 2001 for all birds	1.00
Mammals:						
West Indian manatee	Aquatic (Ensenada Honda)	800	USGS, 2000	21.9	Etheridge et al., 1985	1.00

Notes:

kg/day - dry = Dry weight of food ingested per individual per day.

TABLE 4-2
DIETARY ASSUMPTIONS FOR UPPER TROPHIC LEVEL RECEPTORS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Dietary Composition (percent)				Soil/Sediment Ingestion (percent)	
Receptor	**Soil Invert.**	**Aquatic Plants**	**Aquatic Invert.**	**Reference**	**Value**	**Reference**
Birds:						
American robin	90.9	0	0	Martin et al., 1951	9.1	Sample and Suter II, 1994
Spotted sandpiper	0	0	81.9	USEPA, 1993	18.1	Beyer et al., 1994
Mammals:						
West Indian manatee	0	99.0	0	USFWS, 1986 and Odell, 1992	1.0	USGS, 2000

Notes:

USEPA = United States Environmental Protection Agency
USFWS = United States Fish and Wildlife Service
USGS = United States Geological Survey

TABLE 4-3
INGESTION-BASED SCREENING VALUES FOR BIRDS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Chemical	Test Organism	Body Weight (kg)	Duration	Exposure Route	Effect/Endpoint	Test Material	LOAEL (mg/kg/d)	NOAEL (mg/kg/d)	Reference	Ecological Receptors
Organochlorine Pesticides:										
4,4'-DDD	American kestrel	0.115	2 years	Oral	Reproduction	Not Applicable	0.50	0.05	McLane and Hall, 1972	Amercian robin and spotted sandpiper
4,4'-DDE	American kestrel	0.115	2 years	Oral	Reproduction	Not Applicable	0.50	0.05	McLane and Hall, 1972	American robin and spotted sandpiper
4,4'-DDT	American kestrel	0.115	2 years	Oral	Reproduction	Not Applicable	0.50	0.05	McLane and Hall, 1972	American robin and spotted sandpiper
Inorganics:										
Cadmium	Mallard duck	1.153	90 days	Oral in diet	Reproduction	Cadmium chloride	20	1.45	Sample et al., 1996	American robin and spotted sandpiper
Copper	One-day old chicks	0.534	10 weeks	Oral in diet	Growth/mortality	Copper oxide	61.7	47.0	Sample et al., 1996	American robin and spotted sandpiper
Lead	Japanese quail	0.15	12 weeks	Oral in diet	Reproduction	Lead acetate	11.3	1.13	Sample et al., 1996	American robin and spotted sandpiper
Mercury	Mallard duck	1.00	3 generations	Oral in diet	Reproduction	Methyl mercury dicyandiamide	0.064	0.0064	Sample et al., 1996	American robin and spotted sandpiper
	Japanese quail	0.15	1 year	oral in diet	Reproduction	Mercuric chloride	0.9	0.45	Sample et al., 1996	American robin and spotted sandpiper
Zinc	White leghorn hen	1.935	44 weeks	Oral in diet	Reproduction	Zinc sulfate	131	14.5	Sample et al., 1996	American robin and spotted sandpiper

Notes:

NOAEL = No Observed Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level

TABLE 4-4

INGESTION-BASED SCREENING VALUES FOR MAMMALS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Chemical	Test Organism	Body Weight (kg)	Duration	Exposure Route	Effect/Endpoint	Test Material	Test Species LOAEL (mg/kg-bw/d)	Test Species NOAEL (mg/kg-bw/d)	Reference	Ecological Receptor [1]	Receptor Species [1] LOAEL (mg/kg-bw/d)	Receptor Species [1] NOAEL (mg/kg-bw/d)
Inorganics:												
Arsenic	Mouse	0.03	3 generations	Oral in water	Reproduction	Arsenite (As^{+3})	1.26	0.126	Sample et al., 1996	West Indian manatee	0.093	0.0093
Cadmium	Mouse	0.03	2 generations	Oral in water	Reproduction	? (soluble salt)	2.52	0.252		West Indian manatee	0.187	0.0187
Copper	Mink	1.00	357 days	Oral in diet	Reproduction	Copper Sulfate	15.14	11.7	Sample et al., 1996	West Indian manatee	2.692	2.0806
Lead	Rat	0.35	3 generations	Oral in diet	Reproduction	Lead Acetate	80.0	8.0	Sample et al., 1996	West Indian manatee	10.942	1.0942
Mercury	Mink	1.00	93 days	Oral in diet	Mortality/weight loss	Methyl Mercury Chloride (CH_3HgCl)	0.025	0.015	Sample et al., 1996	West Indian manatee	0.004	0.0027
	Mink	1.00	6 months	Oral in diet	Reproduction	Mercuric Chloride ($HgCL_2$)	1.0	10.0	Sample et al., 1996	West Indian manatee	0.178	1.7783
Selenium	Rat	0.35	1 year	Oral in water	Reproduction	Potassium Selenate (SeO_4)	0.33	0.20	Sample et al., 1996	West Indian manatee	0.045	0.0274
Zinc	Mink	1.00	25 weeks	Oral	Reproduction	?	208	20.8	ATSDR, 1992b	West Indian manatee	36.988	3.6988

Notes:

mg/kg-bw/day = milligrams per kilogram-body weight per day
NOAEL = No Observed Effect Level
LOAEL = Lowest Observed Effect Level
ASTDR = Agency for Toxic Substances and Disease Registry

[1] NOAEL and LOAEL values adjusted to reflect differences in body weights between the mammalian test species and the West Indian manatee.

TABLE 4-5
DECISION RULES
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Line of Evidence	Decision Based on	Uncertainties/ Limitations/ Factors to Consider	Decision Criteria	Decision Recommendations/Actions
Comparison of the spatial and statistical distributions (maximum, mean, and 95% UCL concentrations) in SWMUs 1 and 2 soil and SWMU 2 estuarine wetland sediment	Do the maximum, mean, and 95% UCL soil and estuarine wetland sediment concentrations exceed acceptable media-specific toxicological thresholds? What is the spatial pattern of exceedance of these criteria?	Literature-based toxicological thresholds are not site-specific (do not take into consideration site-specific factors that can influence bioavailability)	HQ > 1.0	Indication of unacceptable risk
			HQ $\leq$ 1.0	Indication of acceptable/minimal risk
Comparison of SWMU 2 estuarine wetland sediment molar AVS concentrations to molar SEM concentrations	Does the molar concentration of AVS in SWMU 2 estuarine wetland sediment exceed the molar concentration of SEM metals (cadmium, copper, lead, nickel, silver, and zinc)	Prediction of the absence or presence of toxicity	AVS/SEM < 1.0	Indication of unacceptable risk
			AVS/SEM > 1.0	Indication of acceptable/minimal risk
Comparisons of toxic response to reference areas	Is there a significant reduction ($\alpha = 0.05$) in the survival, growth, and/or reproduction of *Eisenia fetida* exposed to SWMUs 1 and 2 soil and reference soil, survival, growth, and/or reproduction of *Leptocheirus plumulosus* exposed to SWMU 2 estuarine wetland sediment and reference estuarine wetland sediment, and survival and growth of *Neanthes arenaceodentata* exposed to SWMU 2 estuarine wetland sediment and estuarine wetland sediment?	Low control or reference survival, growth, and/or reproduction - potential inability to make decision; Power of toxicity and statistical tests	$p < 0.05$, significant difference	Unacceptable risk identified; Risk remediation considerations recommended
			$p \geq 0.05$, non significant difference	Indication of acceptable/minimal risk; No further action recommended

TABLE 4-5
DECISION RULES
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Line of Evidence	Decision Based on	Uncertainties/ Limitations/ Factors to Consider	Decision Criteria	Decision Recommendations/Actions
Demonstration of a dose-response relationship between chemical concentrations and toxicity test endpoint response variables	Does a response relationship exists (indicated by multiple regression with a $p < 0.05$ and $r^2 > 0.50$) between potential ecological risk drivers and the most sensitive of the measured response variables (survival, growth, or reproduction for *Eisenia fetida* and *Leptocheirus plumulosus*; survival or growth for *Neanthes arenaceodentata*)?	Confounding influences may include the use of inappropriate reference samples, inability of field effort to capture known concentration gradient of risk drivers, response variables outside of concentration ranges, and physical/chemical (grainsize, TOC, pH, etc.) parameters impacting the response variable.	$p < 0.05$ and $r^2 \geq 0.50$, significant difference, low variability in response	Unacceptable risk identified; Risk remediation considerations recommended
			$p<0.05$ and $r^2<0.50$ significant difference, high variability in response	Large variability in response variable caused by confounding variables; Investigation into variable impact and weight to arrive at decision point
			$p \geq 0.05$, non significant difference	Indication of acceptable/minimal risk only after investigation of the limits and uncertainties associated with the potential for confounding influences; No further action recommended
Comparison of dietary intakes for terrestrial avian omnivores (American robin; SWMUs 1 and 2), aquatic avian invertebrate consumers (spotted sandpiper; SWMU 2), and West Indian manatees (SWMUs 1 and 2) to literature-based toxicity reference values	Do dietary dose estimates using earthworm tissue data (American robin), fiddler crab tissue data (spotted sandpiper), and seagrass tissue data (West Indian manatee) exceed literature-based NOAEL and LOAEL ingestion-based screening values?	Site-specific bioaccumulation	HQ > 1.0	Indication of unacceptable risk
			HQ $\leq$ 1.0	Indication of acceptable/minimal risk

Notes:

HQ = Hazard Quotient
UCL = Upper Confidence Limit
TOC = Total Organic Carbon
NOAEL = No Observed Adverse Effect Concentration
LOAEL = Lowest Observed Adverse Effect Levels
SWMU = Solid Waste Management Unit

TABLE 5-1
SAMPLING SUMMARY: VERIFICATION OF THE BASELINE ECOLOGICAL RISK ASSESSMENT FIELD SAMPLING DESIGN
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Laboratory Parameter	Samples (1)			Quality Assurance/Quality Control				Total Number of Samples
		SWMU 1	SWMU 2	Reference Area (2)	Field Duplicates (3)	MS/MSD (4)	Field Blank	Equipment Rinsate Blank (5)	
Surface Soil (0 to 1.0 foot bgs)	LL-PAHs (6), Appendix IX organochlorine pesticides, and Appendix IX metals			6	1	1	1	1	10
	Total antimony, cadmium, copper, lead, mercury, tin, and zinc; 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT	6	6	6					18
	TOC	6	6	12					24
	Grain size	6	6	12					24
	pH	6	6	12					24
Suburface Soil (1.0 to 2.0 feet bgs)	LL-PAHs (6), Appendix IX organochlorine pesticides, and total Appendix IX metals			6	1	1	1	1	10
	Total antimony copper, lead, mercury, and zinc		6	6 (7)					12
	TOC		6	12					18
	Grain size		6	12					18
	pH		6	12					18
Estuarine Wetland Sediment (0 to 0.5 feet bgs)	Total copper, lead, mercury, and zinc			6	1	1			8
	Ammonia		6	6					12
	Sulfide		6	6					12
	TOC			6					6
	Grain size		6	6					12
	pH		6	6					12

Notes:

MS/MSD = Matrix Spike/ Matrix Spike Duplicate
SWMU = Solid Waste Management Unit
TOC = Total Organic Carbon
bgs = Below Ground Surface
LL-PAHs = Low Level Polycyclic Aromatic Hydrocarbons

(1) The actual number of SWMU and reference samples submitted for analysis may vary based on conditions encountered in the field.

(2) Three potential upland reference areas will be evaluated during verification of the field sampling design (see Figure 5-1). Four surface and four subsurface samples will be collected within each proposed reference area (two surface and two subsurface soil samples from each reference area will be analyzed for LL-PAHs, Appendix IX metals, and Appendix IX organochlorine pesticides; two surface soil and two subsurface soil samples from each reference area will be analyzed for antimony, cadmium, copper, lead, mercury, tin, zinc, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT).

TABLE 5-1
SAMPLING SUMMARY: VERIFICATION OF THE BASELINE ECOLOGICAL RISK ASSESSMENT FIELD SAMPLING DESIGN
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Notes (continued)

(3) Field duplicates will be collected at a frequency of 10% (1/10 samples).

(4) MS/MSD samples will be collected at a frequency of 5% (1/20 samples).

(5) The actual number of equipment rinsate blanks collected will depend on the different types of field sampling equipment used to collect a given medium.

(6) 1-Methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, (benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenathrene, and pyrene.

(7) Reference area subsurface soil samples and associated QA/QC also will be analyzed for potential ecological risk drivers unique to SWMU 2 surface soil (cadmium, tin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT).

TABLE 5-2
SAMPLING SUMMARY: BASELINE ECOLOGICAL RISK ASSESSMENT FIELD INVESTIGATION
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Laboratory Parameter	Samples [1]		Quality Assurance/Quality Control				Total Number of Samples
		SWMU 1	Reference Area [2]	Field Duplicates [3]	MS/MSD [4]	Field Blank	Equipment Rinsate Blank [5]	
Surface Soil (0 to 1.0 foot bgs)	Total antimony, cadmium, copper, lead, mercury, tin, zinc; 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT (quick-turn)	55	6	7	4	1 [6]	2	75
Surface Soil Toxicity Test Samples (0 to 1.0 foot bgs)	28-day *Eisenia fetida* survival, growth, and reproduction tests	10	3					13
	TOC	10	3					13
	Grain size	10	3					13
	pH	10	3					13
Open Water Sediment (0 to 0.5 foot bgs)	Total arsenic, cadmium, copper, mercury, selenium, and zinc	3	3 [7]	1 [7]	1 [7]		2 [7]	10
	TOC	3	3					6
	Grain Size	3	3					6
Tissue	Earthworm (depurated) - Total antimony, cadmium, copper, mercury, tin, and zinc; 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT; percent lipids	10 [8]	3 [8]					13
	Seagrass (above ground) - Total arsenic, cadmium, copper, mercury, selenium, and zinc	3 [9]	3 [9]					6
	Seagrass (whole-plant) - Total arsenic, cadmium, copper, mercury, selenium, and zinc	3 [9]	3 [9]					6

Notes:

MS/MSD = Matrix Spike/ Matrix Spike Duplicate
TOC = Total Organic Carbon
bgs = Below Ground Surface
SWMU = Solid Waste Management Unit

[1] The actual number of SWMU and reference samples submitted for analysis may vary based on conditions encountered in the field.

TABLE 5-2
SAMPLING SUMMARY: BASELINE ECOLOGICAL RISK ASSESSMENT FIELD INVESTIGATION
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEP 3B AND STEP 4 OF THE AQUATIC BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Notes (continued):

(2) Three upland and open water reference areas may be sampled during the SWMU 1 baseline ecological risk assessment field investigation (see Figure 5-1). The actual number of upland and open water reference areas sampled will depend on analytical results from sampling conducted during verification of the field sampling desigh.

(3) Field duplicates will be collected at a frequency of 10% (1/10 samples).

(4) MS/MSD samples will be collected at a frequency of 5% (1/20 samples).

(5) The actual number of equipment rinsate blanks collected will depend on the different types of field sampling equipment used to collect a given medium.

(6) The field blank also will be analyzed for potential ecological risk drivers unique to SWMU 1 open water sediment (i.e., arsenic and selenium).

(7) Open water reference area sediment samples and associated QA/QC samples also will be analyzed for potential ecological risk drivers unique to SWMU 2 open water sediment (i.e., lead; open water reference area sediment will not be sampled during the SWMU 2 ecological risk assessment field sampling investigation).

(8) Earthworms submitted for analytical chemicstry will be those exposed to SWMU 1 and reference surface soil during toxicity testing. For a given sample, surviving earthworms within each replicate will be composited for analytical testing.

(9) Composite turtle grass (*Thalassia testudium*) samples. Reference area seagrass tissue samples also will be analyzed for those potential ecological risk drivers unique to SWMU 2 open water sediment (i.e., lead; reference area seagrass tissue will not be sampled during the SWMU 2 baseline ecological risk assessment field) sampling investigation).

TABLE 5-3
SAMPLING SUMMARY: BASELINE ECOLOGICAL RISK ASSESSMENT FIELD INVESTIGATION
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Laboratory Parameter	Samples (1)		Quality Assurance/Quality Control				Total Samples
		SWMU 2	Reference Area (2)	Field Duplicates (3)	MS/MSD (4)	Field Blank	Equipment Rinsate Blank (5)	
Surface Soil (0 to 1.0 foot bgs)	Total antimony, copper, lead, mercury, and zinc (quick-turn)	55	6	7	4	1 (6)	2	75
Suburface Soil (1.0 to 2.0 feet bgs)	Total antimony, copper, lead, mercury, and zinc	10	6	2	1			19
Soil Toxicity Test Samples (surface and subsurface soil)	28-day *Eisenia fetida* survival, growth, and reproduction toxicty tests	10	3					13
	TOC	10	3					13
	Grain size	10	3					13
	pH	10	3					13
Estuarine Wetland Sediment (0 to 0.5 feet bgs)	Total copper, lead, mercury, and zinc (quick-turn)	24	6	3	2			35
Estuarine Wetland Sediment Toxicity Test Samples (0 to 0.5 feet bgs)	28-day *Leptocheirus plumulosus* survival, growth, and reproduction tests	7	3					10
	20-day *Neanthes arenaceodentata* survival and growth tests	7	3					10
	AVS/SEM	7	3	1	1			12
	Ammonia	7	3					10
	Sulfide	7	3					10
	TOC	7	3					10
	Grain size	7	3					10
	pH	7	3					10
Open Water Sediment (0 to 0.5 foot bgs)	Total arsenic, cadmium, copper, lead, mercury, selenium, and zinc	3		1	1		2	7
	TOC	3						3
	Grain size	3						3

TABLE 5-3

SAMPLING SUMMARY: BASELINE ECOLOGICAL RISK ASSESSMENT FIELD INVESTIGATION

SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)

STEP 3B AND STEP 4 OF THE AQUATIC BASELINE ECOLOGICAL RISK ASSESSMENT

NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Laboratory Parameter	Samples (1)		Quality Assurance/Quality Control				Total Number of Samples
		SWMU 2	Reference Area (2)	Field Duplicates (3)	MS/MSD (4)	Field Blank	Equipment Rinsate Blank (5)	
Tissue	Earthworm (depurated) - Total antimony, copper, lead, mercury, and zinc; percent lipids	10 (7)	3 (7)					13
	Fiddler crab (non-depurated) - Total lead and mercury; percent lipids	8	4					12
	Seagrass (above ground) - Total arsenic, cadmium, copper, lead, mercury, selenium, and zinc	3 (8)						3
	Seagrass (whole-plant) - Total arsenic, cadmium, copper, lead, mercury, selenium, and zinc	3 (8)						3

Notes:

MS/MSD = Matrix Spike/ Matrix Spike Duplicate
AVS/SEM = Acid Volatile Sulfide/Simultaneously Extrated Metals
TOC = Total organic carbon
SWMU = Solid Waste Management Unit
bgs = Below Ground Surface

(1) The actual number of SWMU and reference samples submitted for analysis may vary based on conditions encountered in the field.

(2) Three upland and open water reference areas may be sampled during the SWMU 1 baseline ecological risk assessment field investigation (see Figure 5-1). The actiual number of upland and open water reference areas sampled will depend on analytical results from sampling conducted during verification of the field sampling design.

(3) Field duplicates will be collected at a frequency of 10% (1/10 samples).

(4) MS/MSD samples will be collected at a frequency of 5% (1/20 samples).

(5) The actual number of equipment rinsate blanks collected will depend on the different types of field sampling equipment used to collect a given medium.

(6) The field blank also will be analyzed for potential ecological risk drivers unique to SWMU 2 open water sediment (i.e., arsenic and selenium).

(7) Earthworms submitted for analytical chemicstry will be those exposed to SWMU 2 and reference area soil during toxicity testing. For a given sample, surviving earthworms within each replicate will be composited for analytical testing.

(8) Composite turtle grass (*Thalassia testudium*) samples.

TABLE 5-4
ANALYTICAL METHODS AND ANALYTICAL DATA LEVELS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Analyte	Analytical Method	Analytical Data Levels	Turn Around Time
Verification of the Field Sampling Design: SWMUs 1 and 2				
Soil	LL-PAHs	SW-846 8270	USEPA Level IV	28 days
	Organochlorine pesticides	SW-846 8081	USEPA Level IV	28 days
	Metals (total)	SW-846 6020/SW-846 7471A (1)	USEPA Level IV	28 days
	TOC	SW-846 9060	USEPA Level III	28 days
	pH	SW-846 9045C	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Estuarine Wetland Sediment	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
	Ammonia	EPA 350.1	USEPA Level III	28 days
	Sulfide	SW-846 9030	USEPA Level III	28 days
	TOC	SW-846 9060	USEPA Level III	28 days
	pH	SW-846 9045C	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Aqueous (2)	LL-PAHs	SW-846 8270	USEPA Level IV	28 days
	Organochlorine pesticides	SW-846 8081	USEPA Level IV	28 days
	Metals (total)	SW-846 6020/SW-846 7471A (1)	USEPA Level IV	28 days
Baseline Ecological Risk Assessment Field Investigation: SWMU 1				
Surface Soil	4,4'-DDT	SW-846 8081	USEPA Level IV	48 hours
	4,4'-DDD	SW-846 8081	USEPA Level IV	48 hours
	4,4'-DDE	SW-846 8081	USEPA Level IV	48 hours
	Antimony (total)	SW-846 6020	USEPA Level IV	48 hours
	Cadmium (total)	SW-846 6020	USEPA Level IV	48 hours
	Copper (total)	SW-846 6020	USEPA Level IV	48 hours
	Lead (total)	SW-846 6020	USEPA Level IV	48 hours
	Mercury (total)	SW-846 7471A	USEPA Level IV	48 hours
	Tin (total)	SW-846 6020	USEPA Level IV	48 hours
	Zinc (total)	SW-846 6020	USEPA Level IV	48 hours
	TOC	SW-846 9060	USEPA Level III	28 days
	pH	SW-846 9045C	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Open Water Sediment	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Selenium (total)	SW-846 7471A	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
	TOC	SW-846 9060	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Earthworm Tissue	4,4'-DDT	SW-846 8081	USEPA Level IV	28 days
	4,4'-DDD	SW-846 8081	USEPA Level IV	28 days
	4,4'-DDE	SW-846 8081	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
	Percent lipids	EPA Region IV Method OB 10/90	USEPA Level III	28 days

TABLE 5-4
ANALYTICAL METHODS AND ANALYTICAL DATA LEVELS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Analyte	Analytical Method	Analytical Data Levels	Turn Around Time
Baseline Ecological Risk Assessment Field Investigation: SWMU 1				
Seagrass Tissue	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Selenium (total)	SW-846 6020	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
Aqueous (2)	4,4'-DDT	SW-846 8081	USEPA Level IV	28 days
	4,4'-DDD	SW-846 8081	USEPA Level IV	28 days
	4,4'-DDE	SW-846 8081	USEPA Level IV	28 days
	Antimony (total)	SW-846 6020	USEPA Level IV	28 days
	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Tin (total)	SW-846 6020	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
Baseline Ecological Risk Assessment Field Investigation: SWMU 2				
Surface and Subsurface Soil	Antimony (total)	SW-846 6020	USEPA Level IV	48 hours
	Copper (total)	SW-846 6020	USEPA Level IV	48 hours
	Lead (total)	SW-846 6020	USEPA Level IV	48 hours
	Mercury (total)	SW-846 7471A	USEPA Level IV	48 hours
	Zinc (total)	SW-846 6020	USEPA Level IV	48 hours
	TOC	SW-846 9060	USEPA Level III	28 days
	pH	SW-846 9045C	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Estuarine Wetland Sediment	Copper (total)	SW-846 6020	USEPA Level IV	48 hours
	Lead (total)	SW-846 6020	USEPA Level IV	48 hours
	Mercury (total)	SW-846 7471A	USEPA Level IV	48 hours
	Zinc (total)	SW-846 6020	USEPA Level IV	48 hours
	AVS/SEM	Laboratory SOP	USEPA Level IV	28 days
	Ammonia	EPA 350.1	USEPA Level III	28 days
	Sulfide	SW-846 9030	USEPA Level III	28 days
	TOC	SW-846 9060	USEPA Level III	28 days
	pH	SW-846 9045C	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Open Water Sediment	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Selenium (total)	SW-846 6020	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
	TOC	SW-846 9060	USEPA Level III	28 days
	Grain size (sieve)	ASTM D422	USEPA Level III	28 days
Earthworm Tissue	Antimony (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
	Percent lipids	EPA Region IV Method OB 10/90	USEPA Level III	28 days

TABLE 5-4
ANALYTICAL METHODS AND ANALYTICAL DATA LEVELS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Matrix	Analyte	Analytical Method	Analytical Data Levels	Turn Around Time
Baseline Ecological Risk Assessment Field Investigation: SWMU 2				
Fiddler Crab Tissue	Lead (total)	SW-846 8081	USEPA Level IV	28 days
	Mercury (total)	SW-846 8081	USEPA Level IV	28 days
	Percent lipids	EPA Region IV Method OB 10/90	USEPA Level III	28 days
Seagrass Tissue	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Selenium (total)	SW-846 6020	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days
Aqueous (2)	Antimony (total)	SW-846 6020	USEPA Level IV	28 days
	Arsenic (total)	SW-846 6020	USEPA Level IV	28 days
	Cadmium (total)	SW-846 6020	USEPA Level IV	28 days
	Copper (total)	SW-846 6020	USEPA Level IV	28 days
	Lead (total)	SW-846 6020	USEPA Level IV	28 days
	Mercury (total)	SW-846 7471A	USEPA Level IV	28 days
	Selenium (total)	SW-846 6020	USEPA Level IV	28 days
	Zinc (total)	SW-846 6020	USEPA Level IV	28 days

Notes:

LL-PAHs = Low Level Polycyclic Aromatic Hydrocarbons
SOP = Standard Operating Procedure
ASTM = American Society for Testing and Materials
SW-846 = Test methods for evaluating solid wastes, physical/chemical methods
TOC = Total Organic Carbon

(1) Mercury by SW-846 7471A.
(2) Aqueous samples include equipment rinsate and field blanks.

TABLE 5-5
METHOD PERFORMANCE LIMITS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE AQUATIC BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Compound	Aqueous MDL (µg/L)	Soil/Sediment MDL (mg/kg)	Tissue MDL (mg/kg)	Method
LL-PAHs:				
1-Methylnaphthalene	0.0075	0.0011	NA	SW-846 8270
2-Methylnaphthalene	0.11	0.0097	NA	SW-846 8270
Acenaphthene	0.016	0.0001	NA	SW-846 8270
Acenaphthylene	0.0083	0.00098	NA	SW-846 8270
Anthracene	0.011	0.0001	NA	SW-846 8270
Benzo(a)anthracene	0.014	0.0001	NA	SW-846 8270
Benzo(a)pyrene	0.016	0.00083	NA	SW-846 8270
Benzo(b)fluoranthene	0.041	0.0011	NA	SW-846 8270
Benzo(g,h,i)perylene	0.023	0.0001	NA	SW-846 8270
Benzo(k)fluoranthene	0.036	0.00085	NA	SW-846 8270
Chrysene	0.015	0.00093	NA	SW-846 8270
Dibenz(a,h)anthracene	0.024	0.0014	NA	SW-846 8270
Fluoranthene	0.0085	0.0011	NA	SW-846 8270
Fluorene	0.012	0.0012	NA	SW-846 8270
Indeno(1,2,3-cd)pyrene	0.033	0.0016	NA	SW-846 8270
Naphthalene	0.0095	0.0012	NA	SW-846 8270
Phenanthrene	0.0086	0.0013	NA	SW-846 8270
Pyrene	0.0086	0.0012	NA	SW-846 8270
Organochlorine Pesticides:				
4,4'-DDD	0.011	0.0003	0.0009	SW-846 8081
4,4'-DDE	0.012	0.0003	0.0009	SW-846 8081
4,4'-DDT	0.014	0.00027	0.00081	SW-846 8081
Aldrin	0.0053	0.00014	NA	SW-846 8081
alpha-BHC	0.0086	0.00052	NA	SW-846 8081
alpha-Chlordane	0.0068	0.00017	NA	SW-846 8081
beta-BHC	0.0057	0.00047	NA	SW-846 8081
gamma-Chlordane	0.013	0.00022	NA	SW-846 8081
delta-BHC	0.0098	0.00023	NA	SW-846 8081
Dieldrin	0.01	0.00035	NA	SW-846 8081
Endosulfan I	0.0064	0.00016	NA	SW-846 8081
Endosulfan II	0.011	0.00027	NA	SW-846 8081
Endosulfan sulfate	0.01	0.00037	NA	SW-846 8081

TABLE 5-5
METHOD PERFORMANCE LIMITS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE AQUATIC BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Compound	Aqueous MDL (µg/L)	Soil/Sediment MDL (mg/kg)	Tissue MDL (mg/kg)	Method
Organochlorine Pesticides:				
Endrin	0.01	0.00032	NA	SW-846 8081
Endrin aldehyde	0.017	0.00065	NA	SW-846 8081
gamma-BHC	0.0055	0.00014	NA	SW-846 8081
Heptachlor	0.0076	0.00032	NA	SW-846 8081
Heptachlor epoxide	0.015	0.00012	NA	SW-846 8081
Methoxychlor	0.024	0.00047	NA	SW-846 8081
Toxaphene	0.88	0.012	NA	SW-846 8081
Total Metals:				
Antimony	1.0	0.2	NA	SW-846 6020 (ICP-MS)
Arsenic	0.6	0.12	0.098	SW-846 6020 (ICP-MS)
Barium	0.3	0.02	NA	SW-846 6020 (ICP-MS)
Beryllium	0.15	0.03	NA	SW-846 6020 (ICP-MS)
Cadmium	0.1	0.02	0.027	SW-846 6020 (ICP-MS)
Chromium	1.5	0.3	NA	SW-846 6020 (ICP-MS)
Cobalt	0.075	0.15	NA	SW-846 6020 (ICP-MS)
Copper	0.39	0.038	0.011	SW-846 6020 (ICP-MS)
Lead	0.5	0.01	0.0084	SW-846 6020 (ICP-MS)
Mercury	0.08	0.004	0.0037	SW-846 7471A (CVAA)
Nickel	0.15	0.03	NA	SW-846 6020 (ICP-MS)
Selenium	0.5	0.1	0.051	SW-846 6020 (ICP-MS)
Silver	0.25	0.05	NA	SW-846 6020 (ICP-MS)
Thallium	0.25	0.05	NA	SW-846 6020 (ICP-MS)
Tin	1.0	5	NA	SW-846 6020 (ICP-MS)
Vanadium	2.5	0.5	NA	SW-846 6020 (ICP-MS)
Zinc	3.5	0.27	1.4	SW-846 6020 (ICP-MS)
SEM Metals:				
Cadmium	NA	0.032	NA	Laboratory SOP
Copper	NA	0.025	NA	Laboratory SOP
Lead	NA	0.03	NA	Laboratory SOP
Nickel	NA	0.038	NA	Laboratory SOP
Silver	NA	0.014	NA	Laboratory SOP
Zinc	NA	0.11	NA	Laboratory SOP

TABLE 5-5
METHOD PERFORMANCE LIMITS
SWMU 1 (ARMY CREMATOR DISPOSAL SITE) AND SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE AQUATIC BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Notes:

mg/kg = milligrams per kilogram
ug/L = micrograms per liter
CVAA = Cold Vapor Atomic Absorption
MDL = Method Detection Limit
SEM = Simultaneously Extracted Metals
NA = Not Applicable
LL-PAHs = Low Level Polycyclic Aromatic Hydrocarbons
SOP = Standard Operating Procedure

FIGURES

K\CH2M HILL CLEAN III\CTO 108 (106547) 106547L000

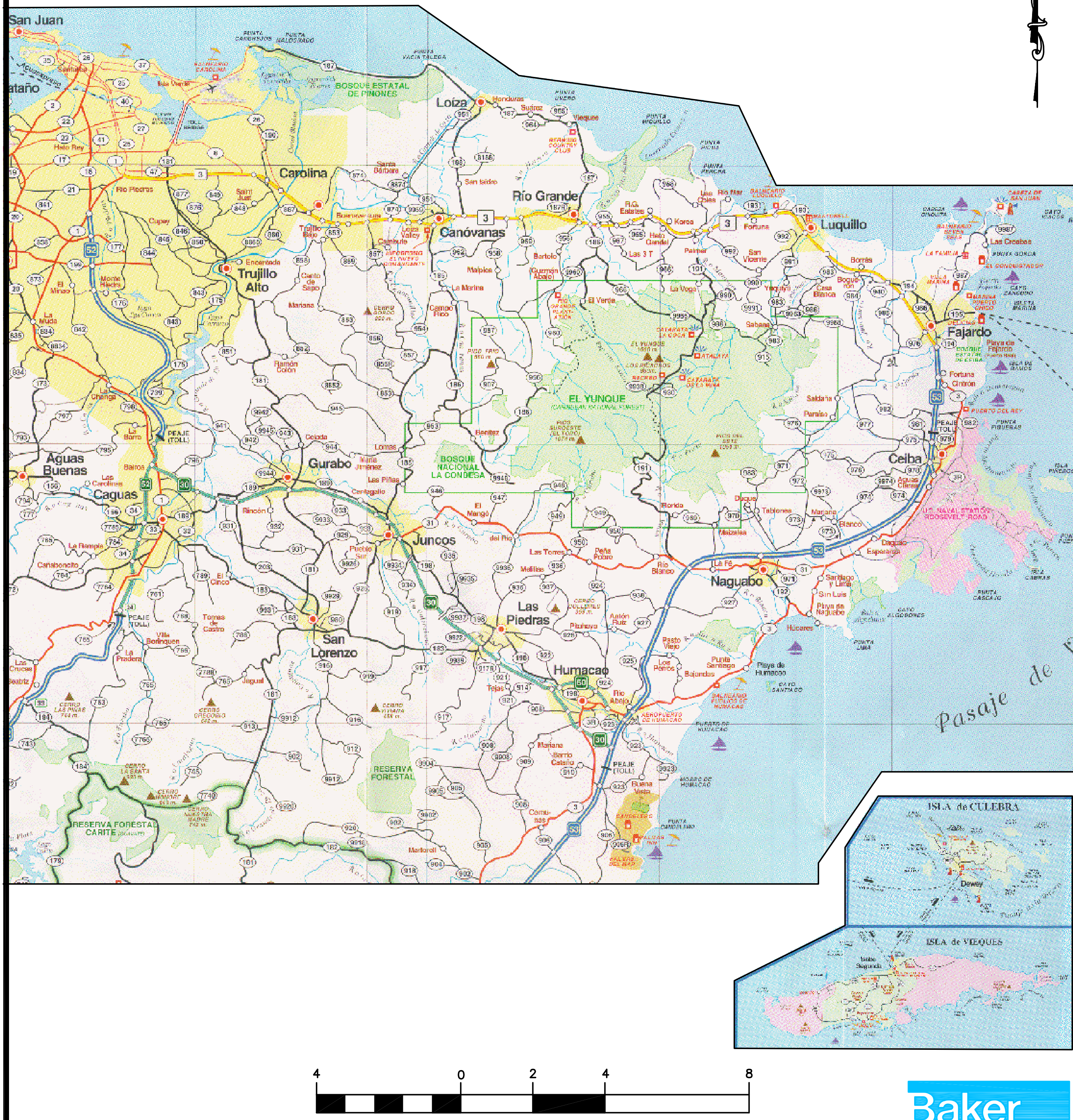
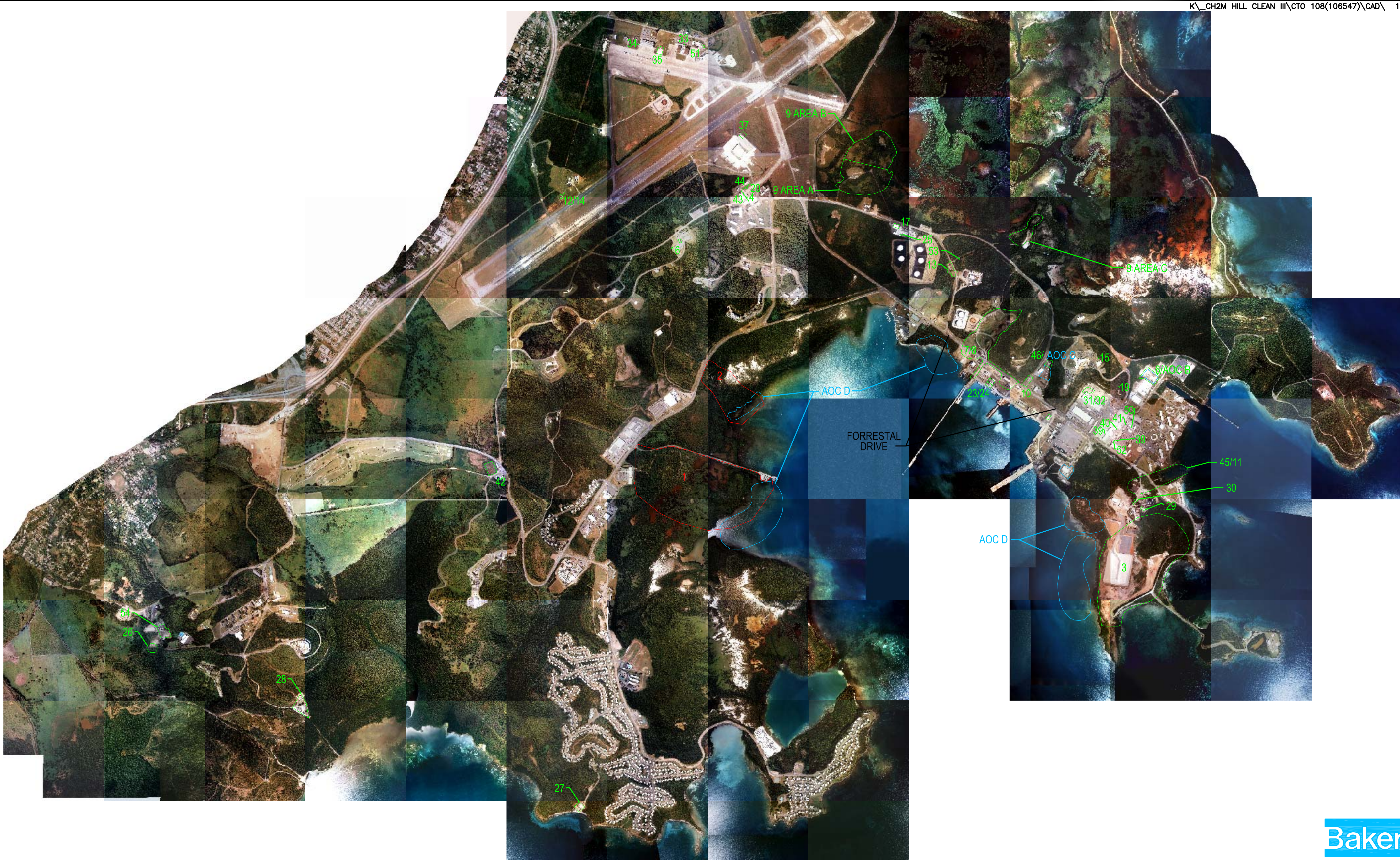


FIGURE 2-1
REGIONAL LOCATION MAP

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

SOURCE: METRODATA, INC., 1999.

K_CH2M HILL CLEAN III\CTO 108(106547)\CAD\ 106547L001



LEGEND

1 – SWMUs

1 – AREA OF WHICH THIS INVESTIGATION PERTAINS TO

AOC D – AOCs

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

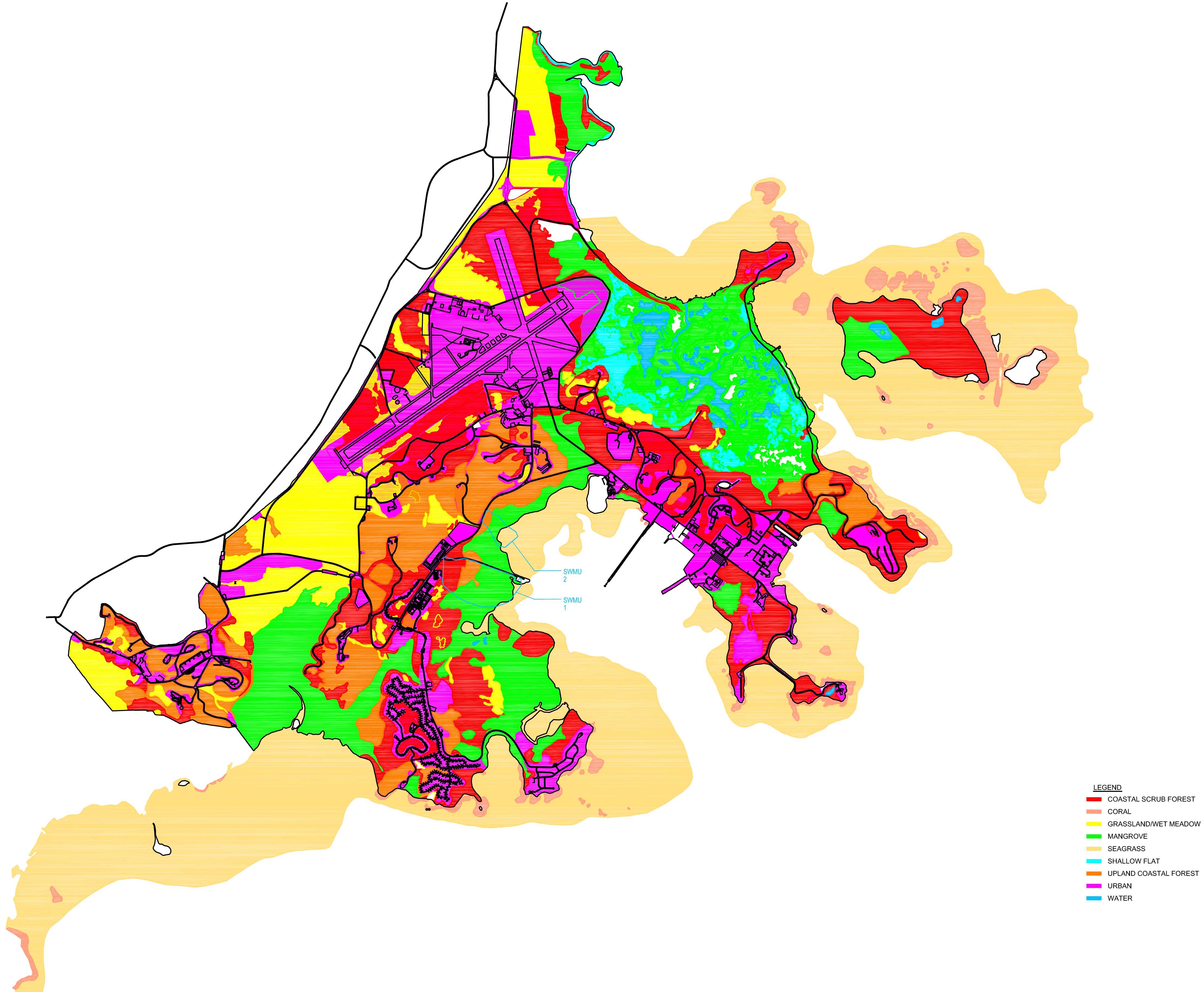
2500 0 1250 2500

1 inch = 2500 ft.

FIGURE 2-2
SWMU/AOC LOCATION MAP

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

Baker



SOURCE: GEO-MARINE, INC.

REVISIONS		NORTH	NAVAL ACTIVITY PUERTO RICO CEIBA, PUERTO RICO		"TERRESTRIAL AND AQUATIC HABITAT OCCURRING AT NAVAL ACTIVITY PUERTO RICO"	FIGURE
	DRAWN /RRR REVIEWED MEK S.O.# 106547 CADD# 106547L002		BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker	SCALE 1" = 600' DATE SEPTEMBER 2006	2-3

Figure 2-4
Naval Activity Puerto Rico Wetlands Delineation North and East Sections

This certifies that this plat identifies potential waters and wetlands regulated persuant to Section 404 of the Clean Water Act. Wetlands were delineated in December, 1999 from 1993 color infrared and 1998 true color aerial photography.

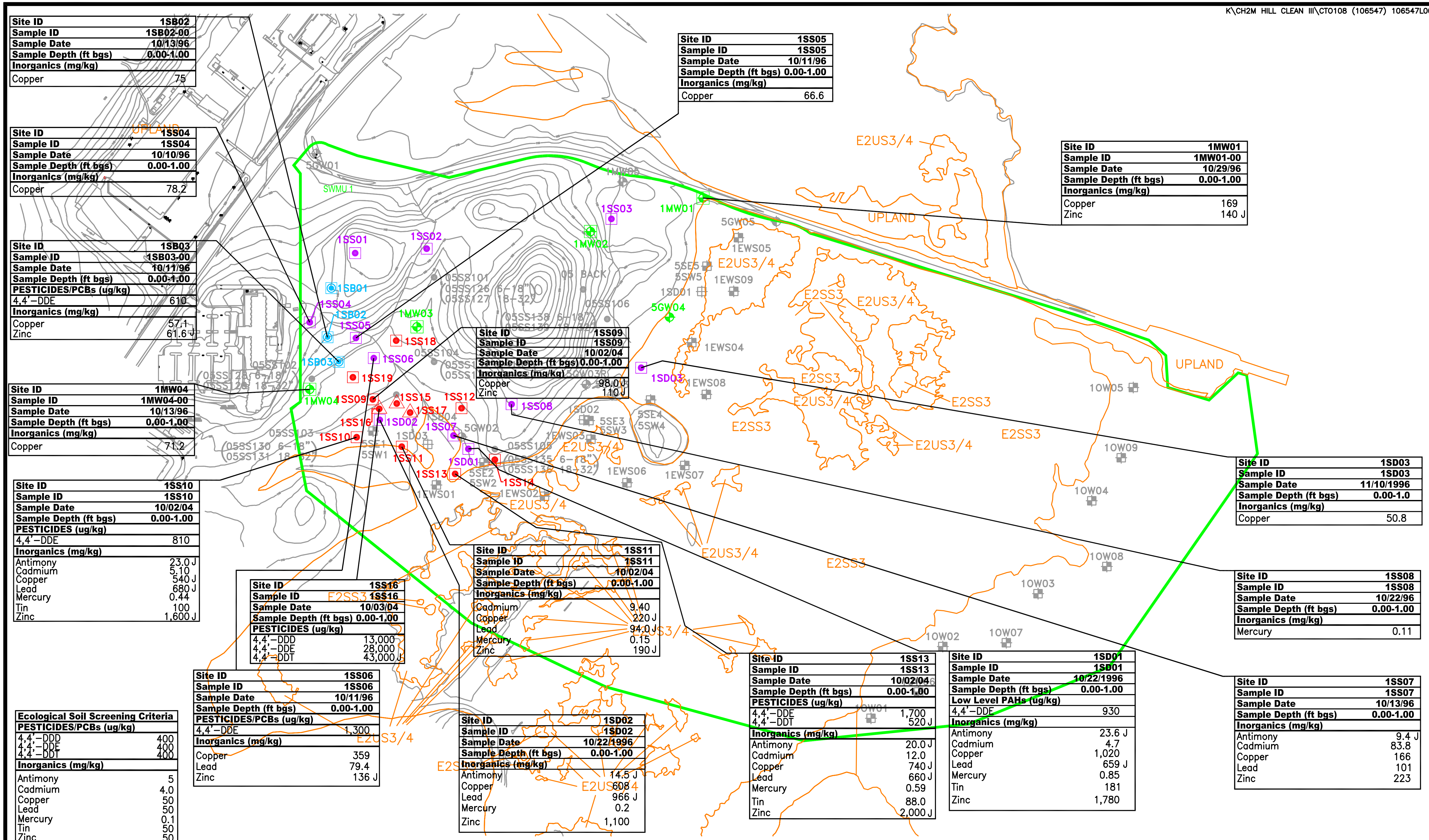
Data form locations
Roosevelt Roads base boundary
Wetland boundaries
SWMU's

N

Source: Geo-Marine, Inc., September 6, 2000

0 750 1,500 3,000 Feet

0 250 500 1,000 Meters



Site ID	1SB02
Sample ID	1SB02-00
Sample Date	10/13/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	75

Site ID	1SS04
Sample ID	1SS04
Sample Date	10/10/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	78.2

Site ID	1SB03
Sample ID	1SB03-00
Sample Date	10/11/96
Sample Depth (ft bgs)	0.00-1.00
PESTICIDES/PCBs (ug/kg)	
4,4'–DDE	610
Inorganics (mg/kg)	
Copper	57.1
Zinc	61.6 J

Site ID	1MW04
Sample ID	1MW04-00
Sample Date	10/13/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	71.2

Site ID	1SS10
Sample ID	1SS10
Sample Date	10/02/04
Sample Depth (ft bgs)	0.00-1.00
PESTICIDES (ug/kg)	
4,4'–DDE	810
Inorganics (mg/kg)	
Antimony	23.0 J
Cadmium	5.10
Copper	540 J
Lead	680 J
Mercury	0.44
Tin	100
Zinc	1,600 J

Site ID	1SS05
Sample ID	1SS05
Sample Date	10/11/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	66.6

Site ID	1MW01
Sample ID	1MW01-00
Sample Date	10/29/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	169
Zinc	140 J

Site ID	1SS09
Sample ID	1SS09
Sample Date	10/02/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	98.0 J
Zinc	110 J

Site ID	1SD03
Sample ID	1SD03
Sample Date	11/10/1996
Sample Depth (ft bgs)	0.00-1.0
Inorganics (mg/kg)	
Copper	50.8

Site ID	1SS08
Sample ID	1SS08
Sample Date	10/22/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Mercury	0.11

Site ID	1SS07
Sample ID	1SS07
Sample Date	10/13/96
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Antimony	9.4 J
Cadmium	83.8
Copper	166
Lead	101
Zinc	223

Site ID	1SS11
Sample ID	1SS11
Sample Date	10/02/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Cadmium	9.40
Copper	220 J
Lead	94.0 J
Mercury	0.15
Zinc	190 J

Site ID	1SS16
Sample ID	1SS16
Sample Date	10/03/04
Sample Depth (ft bgs)	0.00-1.00
PESTICIDES (ug/kg)	
4,4'–DDD	13,000
4,4'–DDE	28,000
4,4'–DDT	43,000 J

Site ID	1SS06
Sample ID	1SS06
Sample Date	10/11/96
Sample Depth (ft bgs)	0.00-1.00
PESTICIDES/PCBs (ug/kg)	
4,4'–DDE	1,300
Inorganics (mg/kg)	
Copper	359
Lead	79.4
Zinc	136 J

Site ID	1SD02
Sample ID	1SD02
Sample Date	10/22/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Antimony	14.5 J
Copper	608
Lead	966 J
Mercury	0.2
Zinc	1,100

Site ID	1SS13
Sample ID	1SS13
Sample Date	10/02/04
Sample Depth (ft bgs)	0.00-1.00
PESTICIDES (ug/kg)	
4,4'–DDE	1,700
4,4'–DDT	520 J
Inorganics (mg/kg)	
Antimony	20.0 J
Cadmium	12.0
Copper	740 J
Lead	660 J
Mercury	0.59
Tin	88.0
Zinc	2,000 J

Site ID	1SD01
Sample ID	1SD01
Sample Date	10/22/1996
Sample Depth (ft bgs)	0.00-1.00
Low Level PAHs (ug/kg)	
4,4'–DDE	930
Inorganics (mg/kg)	
Antimony	23.6 J
Cadmium	4.7
Copper	1,020
Lead	659 J
Mercury	0.85
Tin	181
Zinc	1,780

Ecological Soil Screening Criteria	
PESTICIDES/PCBs (ug/kg)	
4,4'–DDD	400
4,4'–DDE	400
4,4'–DDT	400
Inorganics (mg/kg)	
Antimony	5
Cadmium	4.0
Copper	50
Lead	50
Mercury	0.1
Tin	50
Zinc	50

LEGEND

- 1 – SWMU
- E2SS3 – E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4–4 FOR CLASSIFICATIONS)
- – REPORTED LOCATION OF 5GW03 (NOT LOCATED DURING 1996 RFI FIELD INVESTIGATION)
- – SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- – SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- – SOIL SAMPLE LOCATION (SUPPLEMENTAL INVESTIGATION)
- – SOIL BORING LOCATION (1996 RFI)
- – MONITOR WELL LOCATION (1996 RFI)
- – EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- – SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- – SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- – SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

ESTUARINE WETLAND SYSTEM

- – SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

OPEN WATER MARINE

- – SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

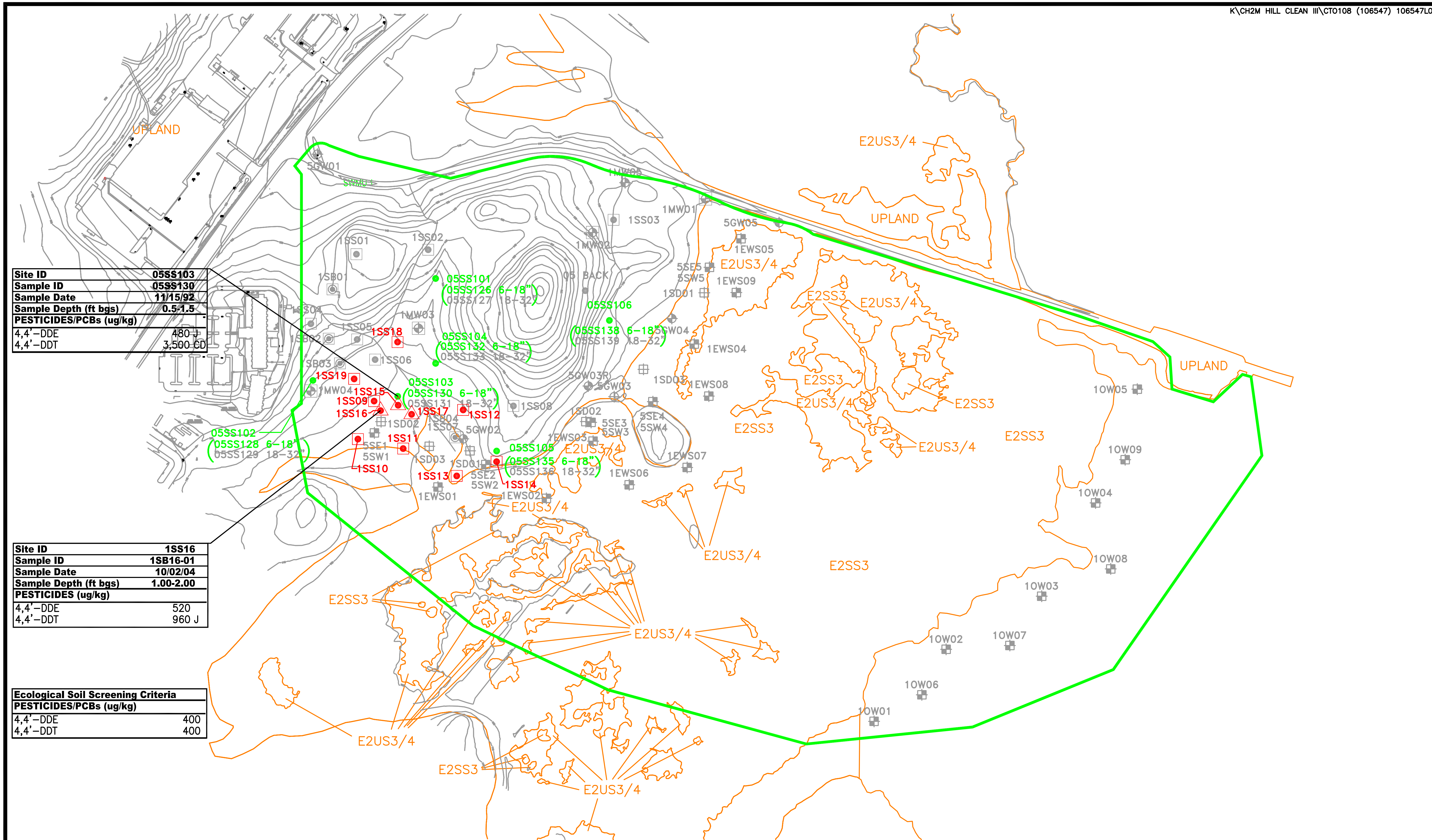
SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

350 0 175 350

1 inch = 350 ft.

Baker

FIGURE 3–1
CONCENTRATIONS OF POTENTIAL ECOLOGICAL RISK DRIVERS IN SWMU 1 SURFACE SOIL EXCEEDING SOIL SCREENING VALUES
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



LEGEND

- SWMU
- E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4–4 FOR CLASSIFICATIONS)
- SEDIMENT SAMPLE LOCATION (1996 RFI)
- REPORTED LOCATION OF 5GW03 (NOT LOCATED DURING 1996 RFI FIELD INVESTIGATION)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

ESTUARINE WETLAND SYSTEM

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

OPEN WATER MARINE

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

350 0 175 350

1 inch = 350 ft.

Baker

FIGURE 3–2
CONCENTRATIONS OF POTENTIAL ECOLOGICAL RISK DRIVERS IN SWMU 1 SUBSURFACE SOIL EXCEEDING SOIL SCREENING VALUES
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

K:\CH2M HILL CLEAN III\CTO 108(106547)\CAD\106547L005

Site ID	2MW02
Sample ID	2MW02-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	110 J
Zinc	107

Site ID	2SB01
Sample ID	2SB01-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	54.7 J
Zinc	62

Site ID	2MW01
Sample ID	2MW01-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	55.1 J
Zinc	52

Site ID	2SB02
Sample ID	2SB02-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	73.6 J
Mercury	0.16 J
Zinc	96.3

Site ID	2SS07
Sample ID	2SS07
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	150
Lead	90
Mercury	0.59 J
Zinc	150

Site ID	2SS04
Sample ID	2SS04
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	76
Mercury	0.11 J
Zinc	95

Site ID	2SD03
Sample ID	2SD03
Sample Date	11/11/1996
Sample Depth (ft bgs)	0.00-1.00
Copper	62.4
Zinc	92.8

Site ID	2SS10
Sample ID	2SS10
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	120
Lead	330
Zinc	1,000

Site ID	2SS01
Sample ID	2SS01
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	190
Lead	77
Mercury	0.18 J
Zinc	520

Site ID	2SB03
Sample ID	2SB03-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Antimony	13.3 J
Copper	374 J
Lead	1,000
Mercury	0.33 J
Zinc	845

Site ID	06SS103
Sample ID	06SS145
Sample Date	11/17/92
Sample Depth (ft bgs)	0.0-0.50
Inorganics (mg/kg)	
Antimony	20.1 J
Copper	739
Lead	4,760 J
Mercury	0.45
Zinc	1,440

Site ID	2SS09
Sample ID	2SS09
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	640
Lead	140
Mercury	0.13 J
Zinc	460

Site ID	2SS03
Sample ID	2SS03
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Antimony	24 J
Copper	270
Lead	1,400
Mercury	0.23 J
Zinc	720

Site ID	2SS14
Sample ID	2SS14
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	83 J
Mercury	0.11 J
Zinc	75

Site ID	2SS05
Sample ID	2SS05
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	880
Lead	280
Mercury	0.15 J
Zinc	800

Site ID	2SD02
Sample ID	2SD02
Sample Date	11/11/1996
Sample Depth (ft bgs)	0.00-1.00
Cobalt	24.9
Copper	399
Lead	390 J
Mercury	0.14
Zinc	841

Site ID	2SS02
Sample ID	2SS02
Sample Date	10/05/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	110
Lead	59
Zinc	130

Site ID	2SS11
Sample ID	2SS11
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	190
Lead	360
Mercury	19.0 J
Zinc	350

Site ID	2SS12
Sample ID	2SS12
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	130
Lead	61
Mercury	0.57 J
Zinc	290

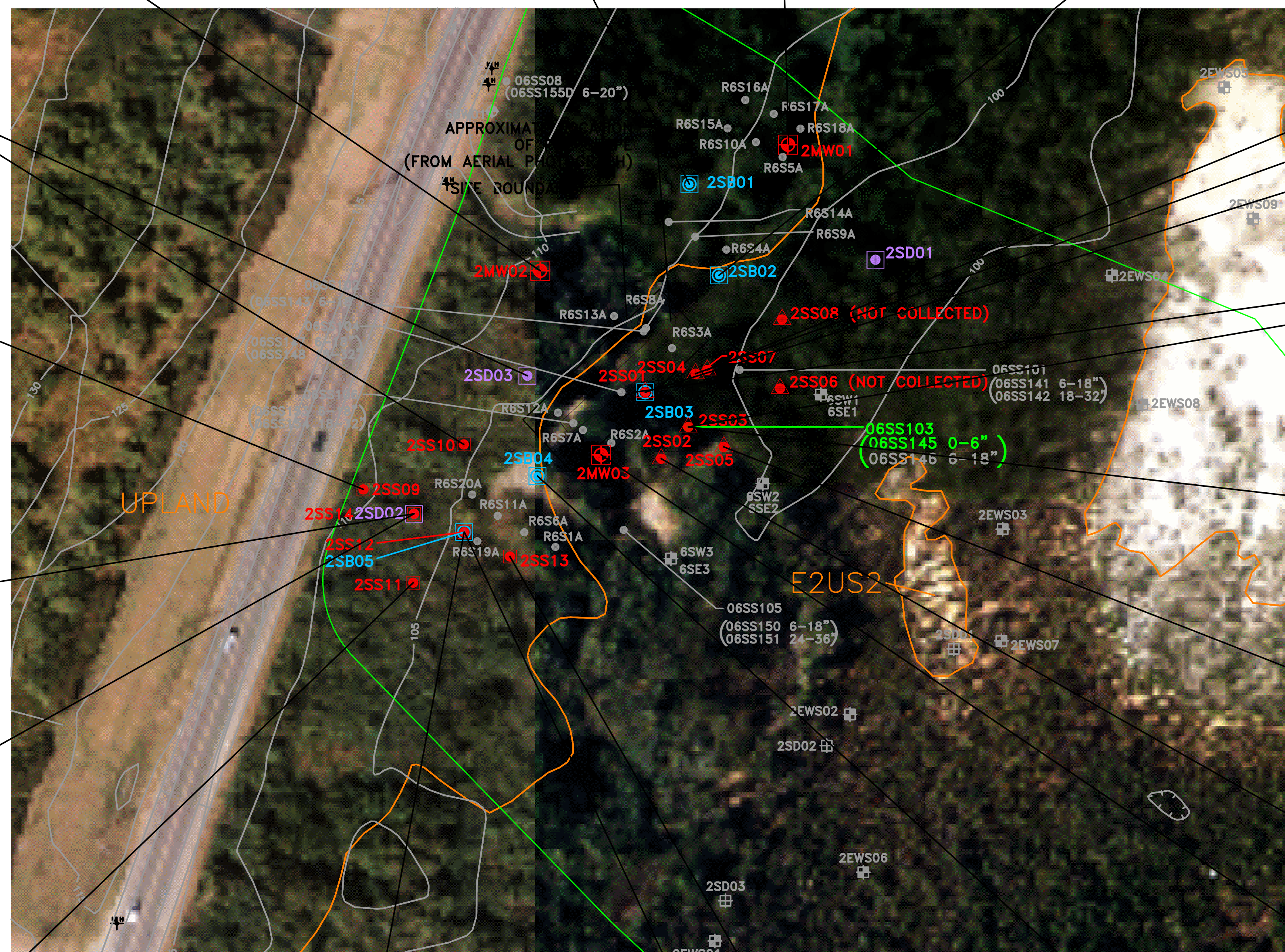
Site ID	2SB05
Sample ID	2SB05-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	919 J
Lead	512
Mercury	0.37 J
Zinc	1,260

Site ID	2SS13
Sample ID	2SS13
Sample Date	10/04/04
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	160
Zinc	150

Site ID	2SB04
Sample ID	2SB04-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	180 J
Lead	156
Zinc	231

Site ID	2MW03
Sample ID	2MW03-00
Sample Date	10/8/1996
Sample Depth (ft bgs)	0.00-1.00
Inorganics (mg/kg)	
Copper	109 J
Lead	60.6
Zinc	108

Ecological Soil Screening Criteria	
Inorganics (mg/kg)	
Antimony	5
Copper	50
Lead	50
Mercury	0.1
Zinc	50



LEGEND

- SWMU
- E2SS3 — E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- ESTUARINE WETLAND SYSTEM
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)
- OPEN WATER MARINE
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

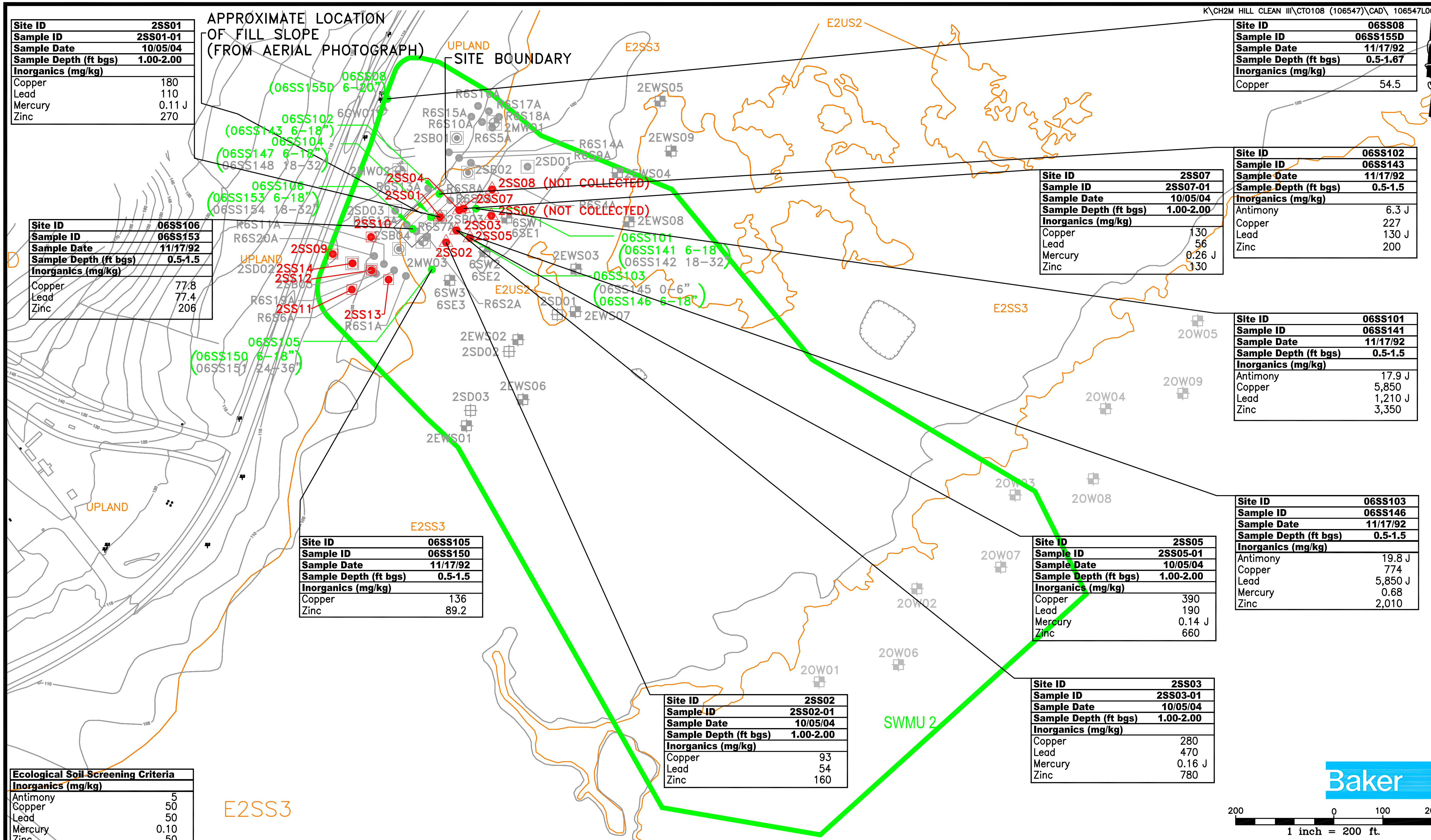
120 0 60 120

1 inch = 120 ft.

Baker

FIGURE 3-3
CONCENTRATIONS OF POTENTIAL ECOLOGICAL RISK DRIVERS IN SWMU 2 SURFACE SOIL EXCEEDING SCREENING VALUES
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.



LEGEND

- SWMU
- E2SS3 — E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

ESTUARINE WETLAND SYSTEM

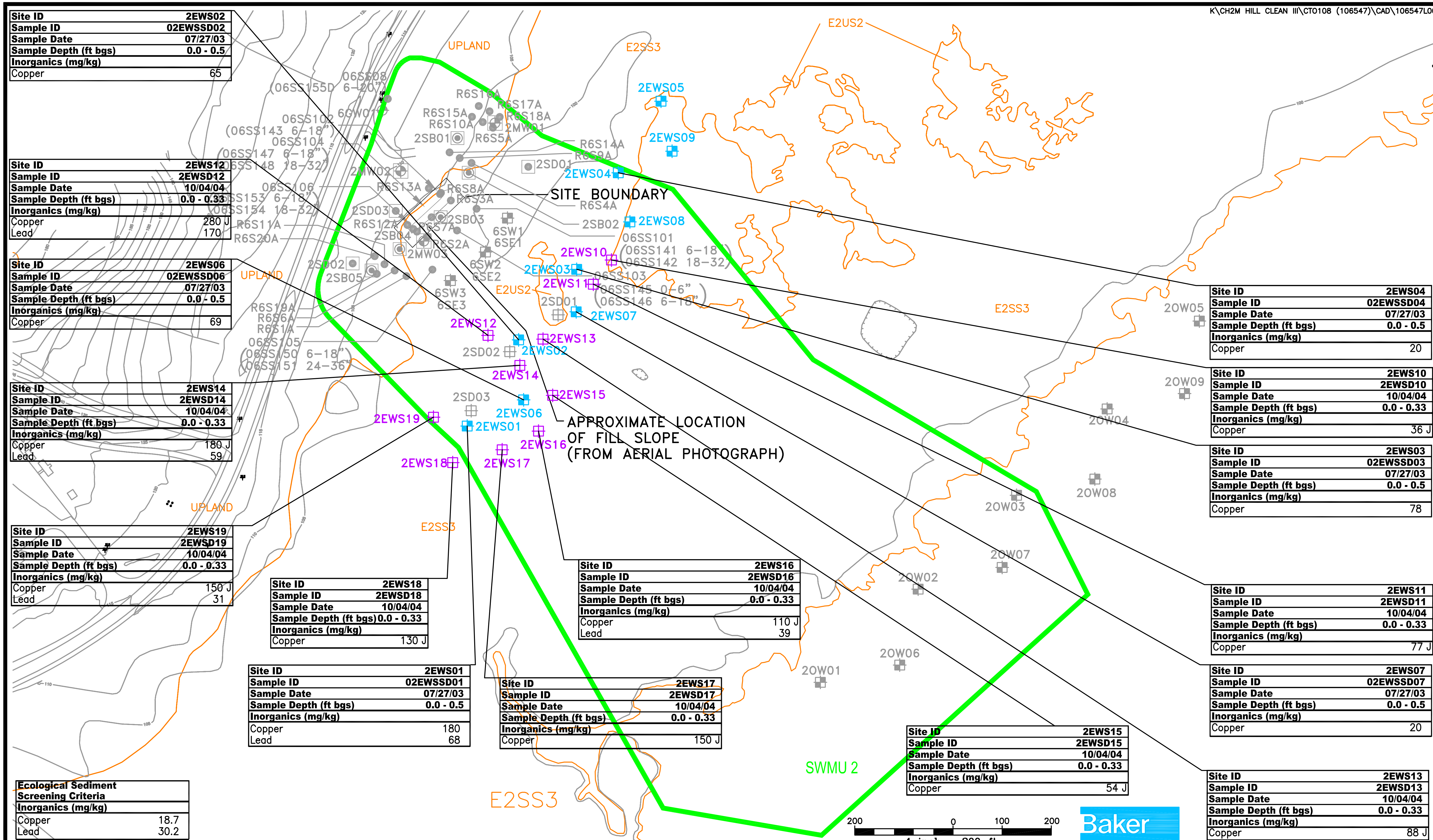
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

OPEN WATER MARINE

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

FIGURE 3-4
CONCENTRATIONS OF POTENTIAL ECOLOGICAL RISK DRIVERS IN SWMU 2 SUBSURFACE SOIL EXCEEDING SOIL SCREENING VALUES
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



LEGEND

- SWMU
- E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)

ESTUARINE WETLAND SYSTEM 2003

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)
- SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

OPEN WATER MARINE 2004

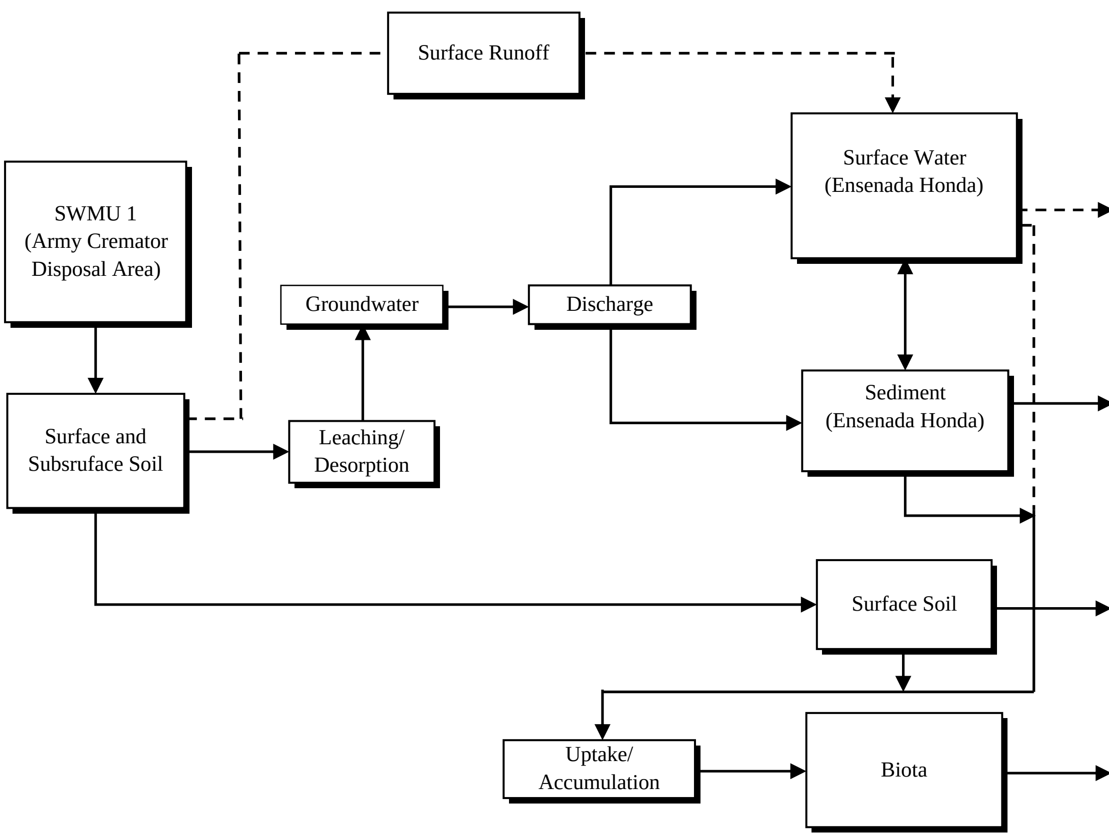
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

FIGURE 3-5
CONCENTRATIONS OF POTENTIAL ECOLOGICAL RISK DRIVERS IN SWMU 2 ESTUARINE WETLAND SEDIMENT EXCEEDING SEDIMENT SCREENING VALUES
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 3-6
REFINED CONCEPTUAL MODEL
SWMU 1 (ARMY CREMATOR DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Source | **Transport Pathways** | **Exposure Media** | **Exposure Route** | **Receptors**

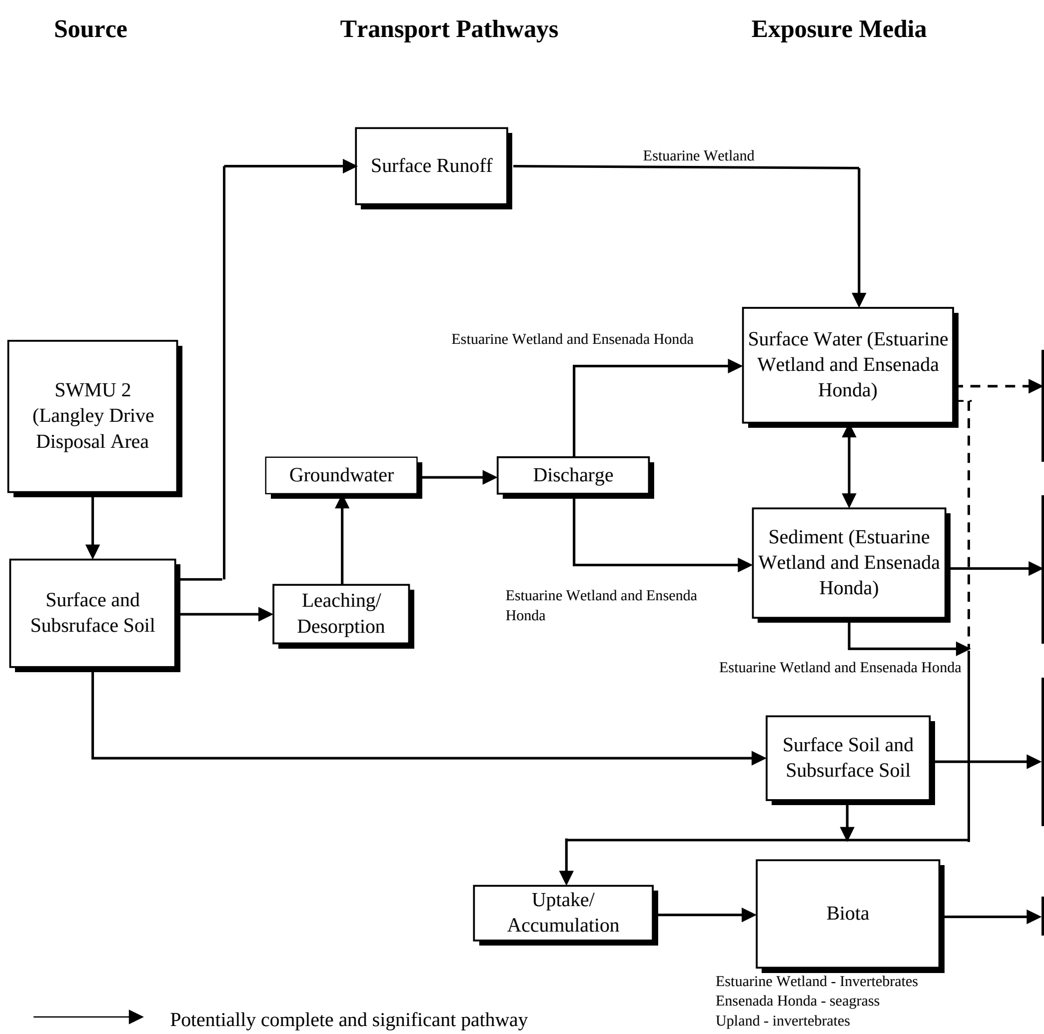


Exposure Media	Exposure Route	Aquatic Plants	Aquatic Invertebrates	Aquatic Fish	Aquatic Reptiles	Aquatic Mammals	Aquatic Birds	Terrestrial Plants	Terrestrial Invertebrates	Terrestrial Amphibians	Terrestrial Reptiles	Terrestrial Birds
Surface Water (Ensenada Honda)	Ingestion		○	○	○	○	○			○	○	○
	Direct Contact	○	○	○	○	○	○					
Sediment (Ensenada Honda)	Ingestion		○	○	○	●	○					
	Direct Contact		○	○	○	○	○					
	Root Uptake	○										
Surface Soil	Ingestion								●	○	○	●
	Direct Contact								●	○	○	○
	Root Uptake							○				
Biota	Ingestion		○	○	○	●	○	○	○	○	○	●

→ (solid arrow) Potentially complete and significant pathway
⇢ (dashed arrow) Potentially complete but insignificant pathway

● Potential for unacceptable risk identified, receptor/pathway quantitatively evaluated in the baseline ecological risk assessment
○ No potential for unacceptable risk identified, no further evaluation required in the baseline ecological risk assessment

FIGURE 3-7
REFINED CONCEPTUAL MODEL
SWMU 2 (LANGLEY DRIVE DISPOSAL SITE)
STEPS 3B AND STEP 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO



Receptors

Exposure Media	Exposure Route	Aquatic: Plants	Aquatic: Invertebrates	Aquatic: Fish	Aquatic: Reptiles	Aquatic: Mammals	Aquatic: Birds	Terrestrial: Plants	Terrestrial: Invertebrates	Terrestrial: Amphibians	Terrestrial: Reptiles	Terrestrial: Birds
Surface Water	Ingestion		○	○	○	○	○			○	○	○
	Direct Contact	○	○	○	○	○	○					
Sediment	Ingestion		●	○	○	●	●					
	Direct Contact		●	○	○	○	○					
	Root Uptake	○										
Surface Soil and Subsurface Soil	Ingestion								●	○	○	●
	Direct Contact								●	○	○	○
	Root Uptake							○				
Biota	Ingestion		○	○	○	●	●	○	○	○	○	●

Estuarine wetland receptors = invertebrates and birds; Ensenada Honda receptors = West Indian mammals (sediment)

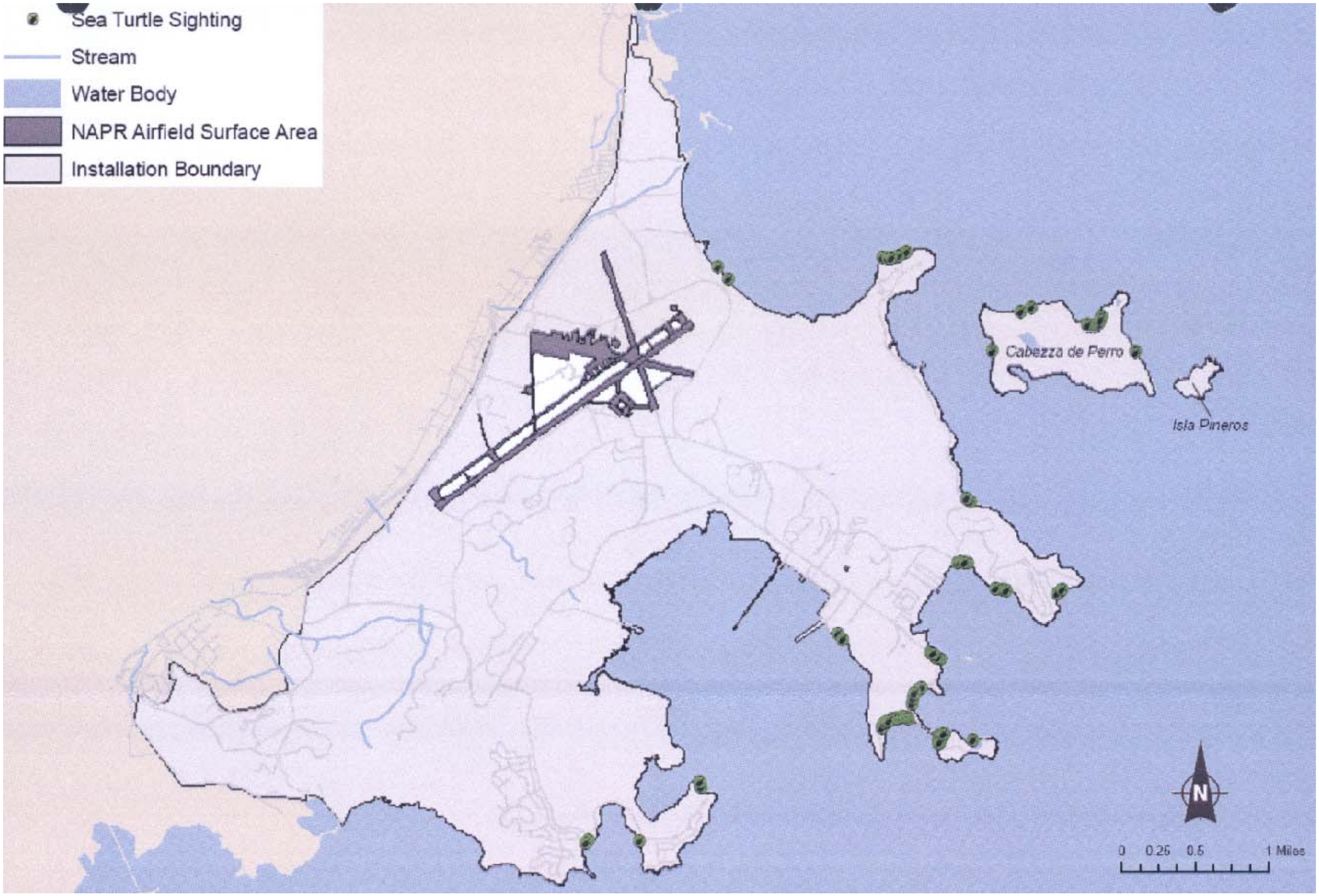
Estuarine wetland receptors = invertebrates and birds; Ensenada Honda receptors = mammals (biota)

→ Potentially complete and significant pathway

- - → Potentially complete but insignificant pathway

● Potential for unacceptable risk identified, receptor/pathway quantitatively evaluated in the baseline ecological risk assessment

○ No potential for unacceptable risk identified, no further evaluation required in the baseline ecological risk assessment

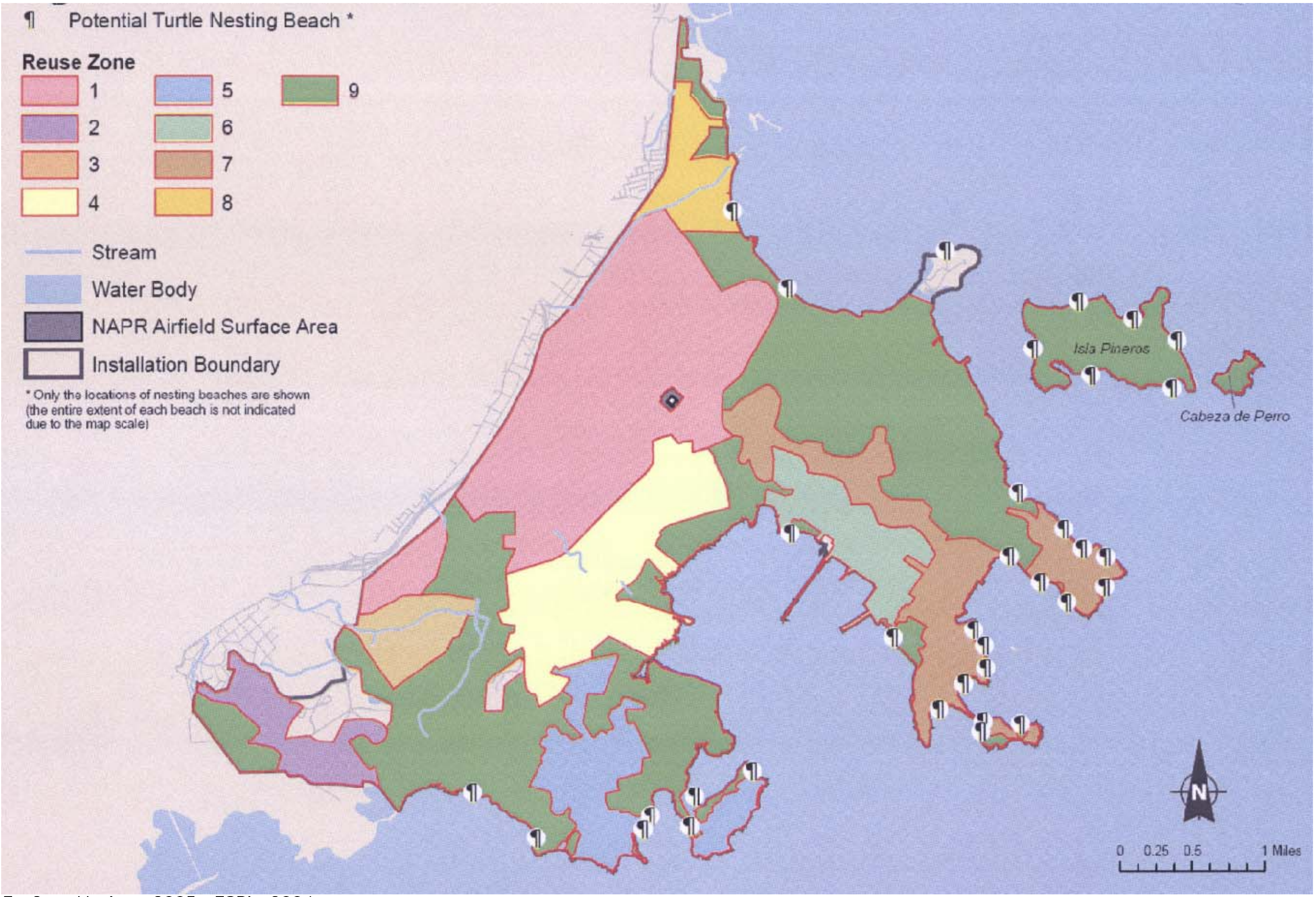


SOURCE: Geo–Marine, 2005; ESRI, 2004; USFW, 2005

Cumulative sea turtle sightings from March 1984 through March 1995 obtained from weekly aerial surveys of NAPR

Figure from: Geo-Marine, Inc. 2005. *Draft Environmental Assessment for the Disposal of Naval Activity Puerto Rico (formerly Naval Station Roosevelt Roads)*. December 2005.

FIGURE 3–8
NAPR SEA TURTLE SIGHTINGS
SWMU 1 AND 2
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



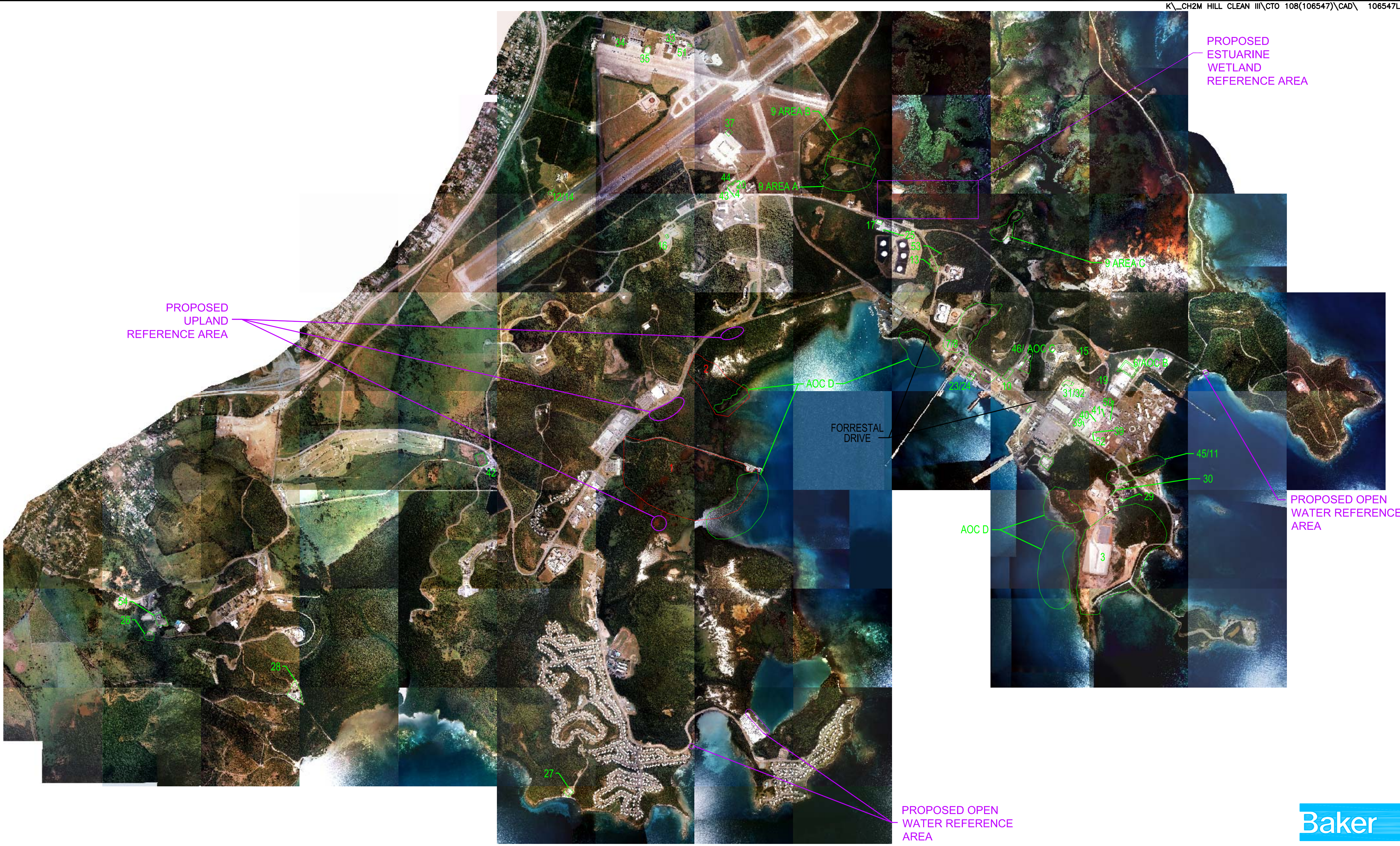
SOURCE: Geo-Marine, 2005; ESRI, 2004;

Cumulative nest sightings from 2002 and 2004 weekly beach nest surveys.

Figure from: Geo-Marine, Inc. 2005. *Draft Environmental Assessment for the Disposal of Naval Activity Puerto Rico (formerly Naval Station Roosevelt Roads)*. December 2005.

FIGURE 3-9
NAPR POTENTIAL SEA TURTLE NESTING HABITAT
SWMU 1 AND 2
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

K_CH2M HILL CLEAN III\CTO 108(106547)\CAD\ 106547L009



LEGEND

SWMUs

AREA OF WHICH THIS INVESTIGATION PERTAINS TO

AOCs

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

2500 0 1250 2500

1 inch = 2500 ft.

FIGURE 5-1
PROPOSED UPLAND, ESTUARINE WETLAND, AND OPEN WATER REFERANCE AREAS FOR SWMU 1

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 5-2

STATISTICAL ANALYSIS PROCESS
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

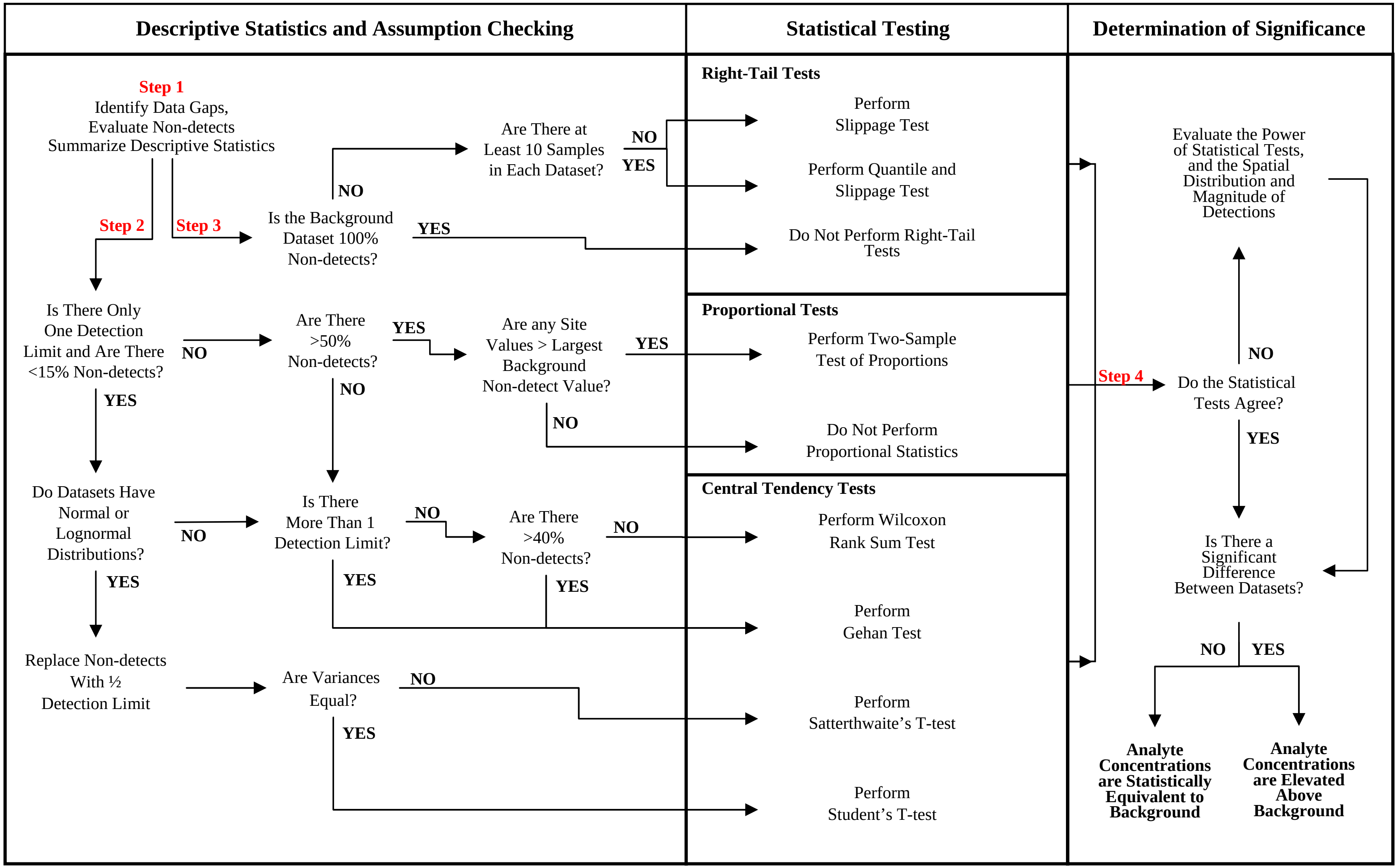
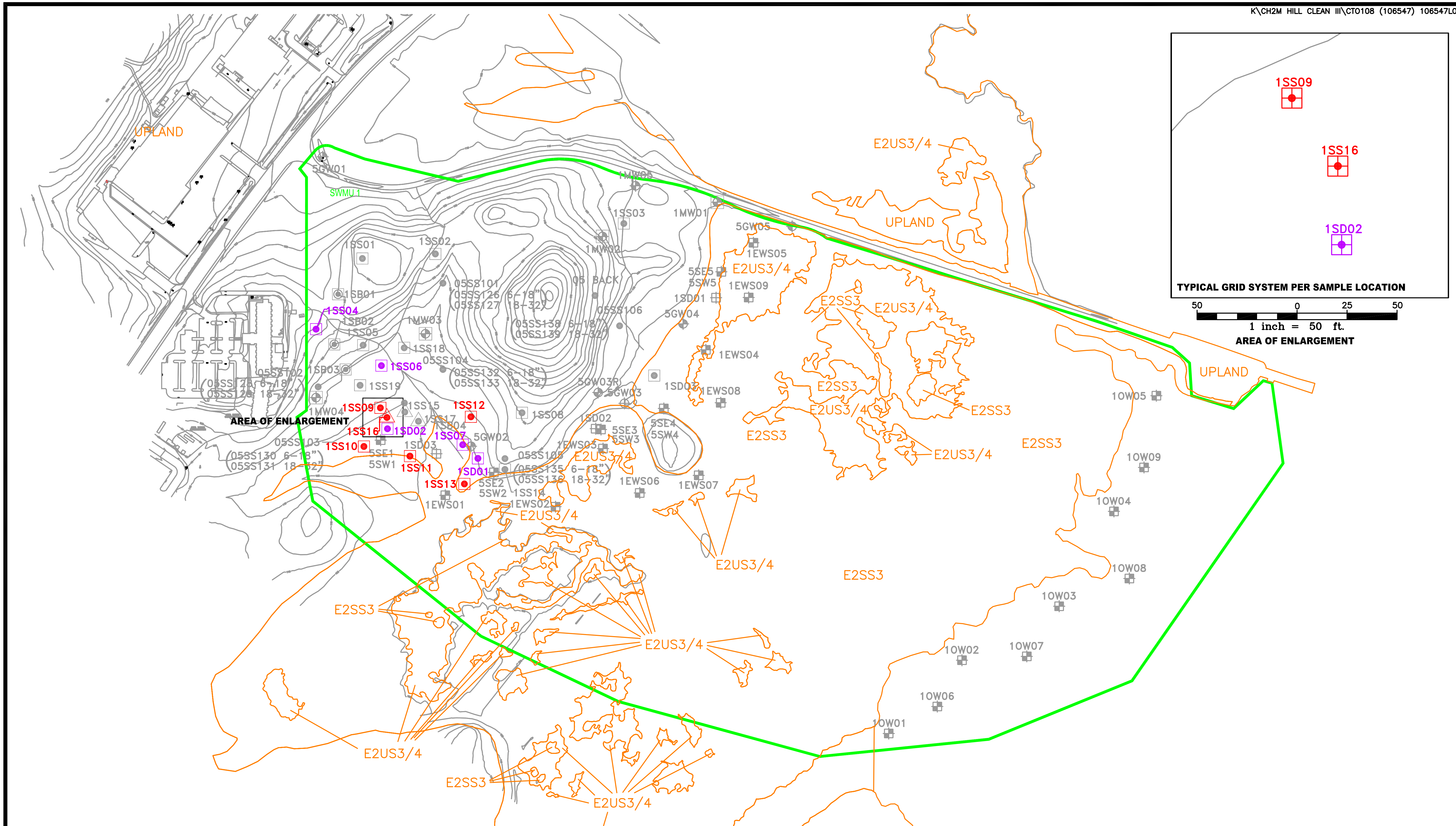


Figure Adapted from NFESC, 1998

T-tests performed on log-transformed data if datasets have lognormal distributions.



NOTE
PROPOSED SAMPLING LOCATIONS IN COLOR

LEGEND

- SWMU
- E2SS3 — E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- REPORTED LOCATION OF 5GW03 (NOT LOCATED DURING 1996 RFI FIELD INVESTIGATION)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

ESTUARINE WETLAND SYSTEM

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

OPEN WATER MARINE

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

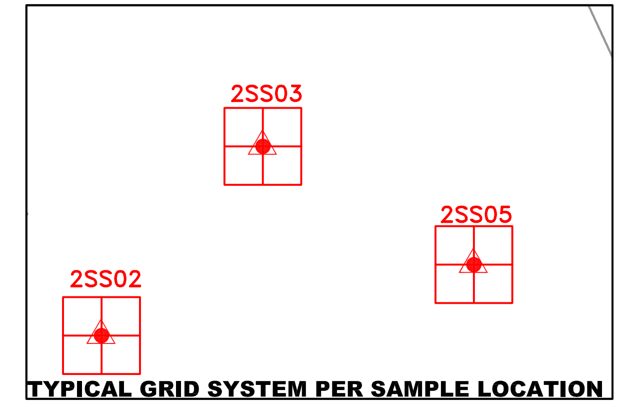
350 0 175 350
1 inch = 350 ft.

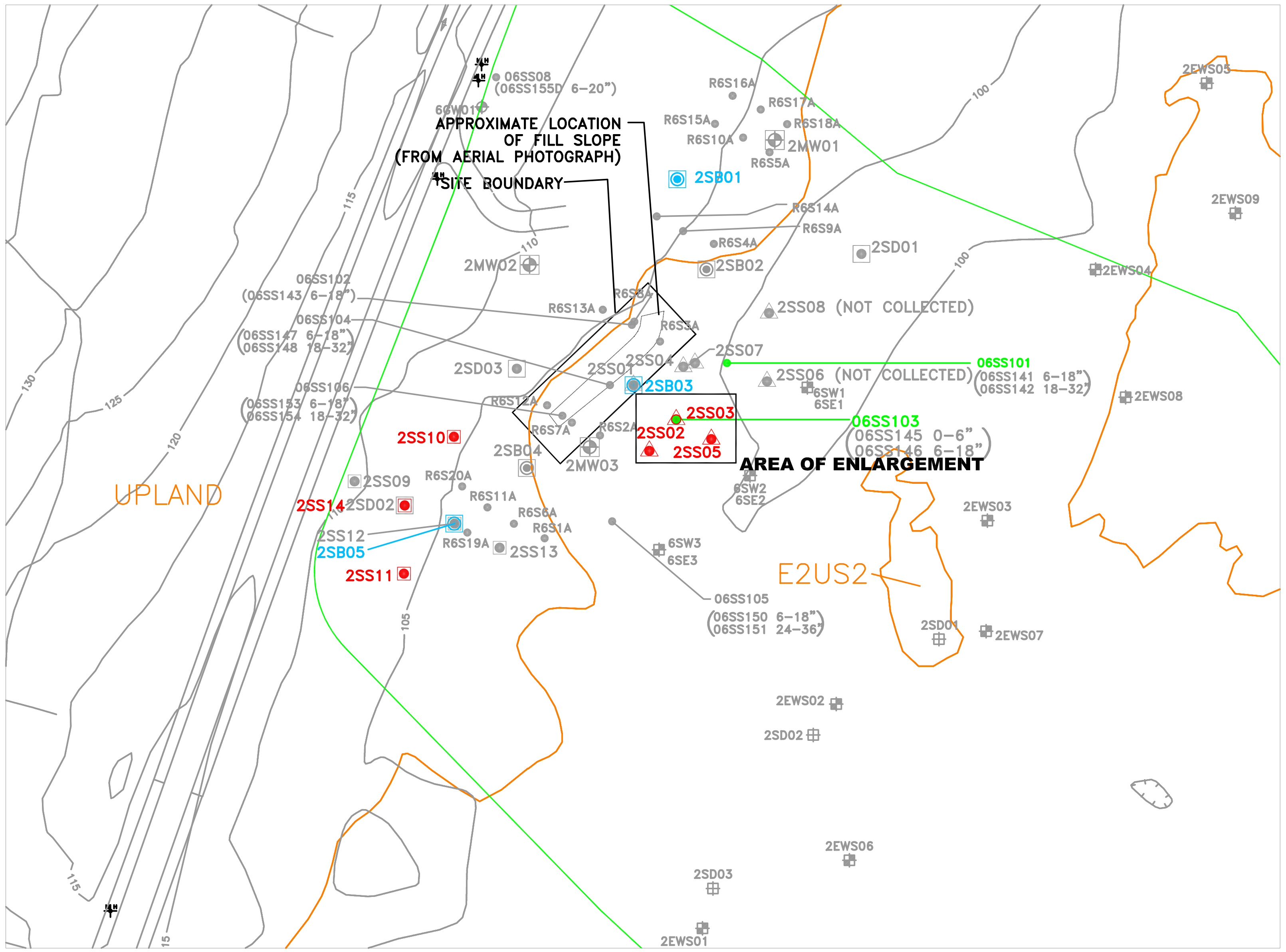
Baker

FIGURE 5-3
PROPOSED SURFACE SOIL SAMPLING LOCATIONS SWMU 1

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

K:\CH2M HILL CLEAN III\CTO108 (106547) 106547L011





NOTE
PROPOSED SAMPLING LOCATIONS IN COLOR

LEGEND

- SWMU
- E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4–4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)
- SURFACE AND SUBSURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)
- SURFACE SOIL SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

ESTUARINE WETLAND SYSTEM
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

OPEN WATER MARINE
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

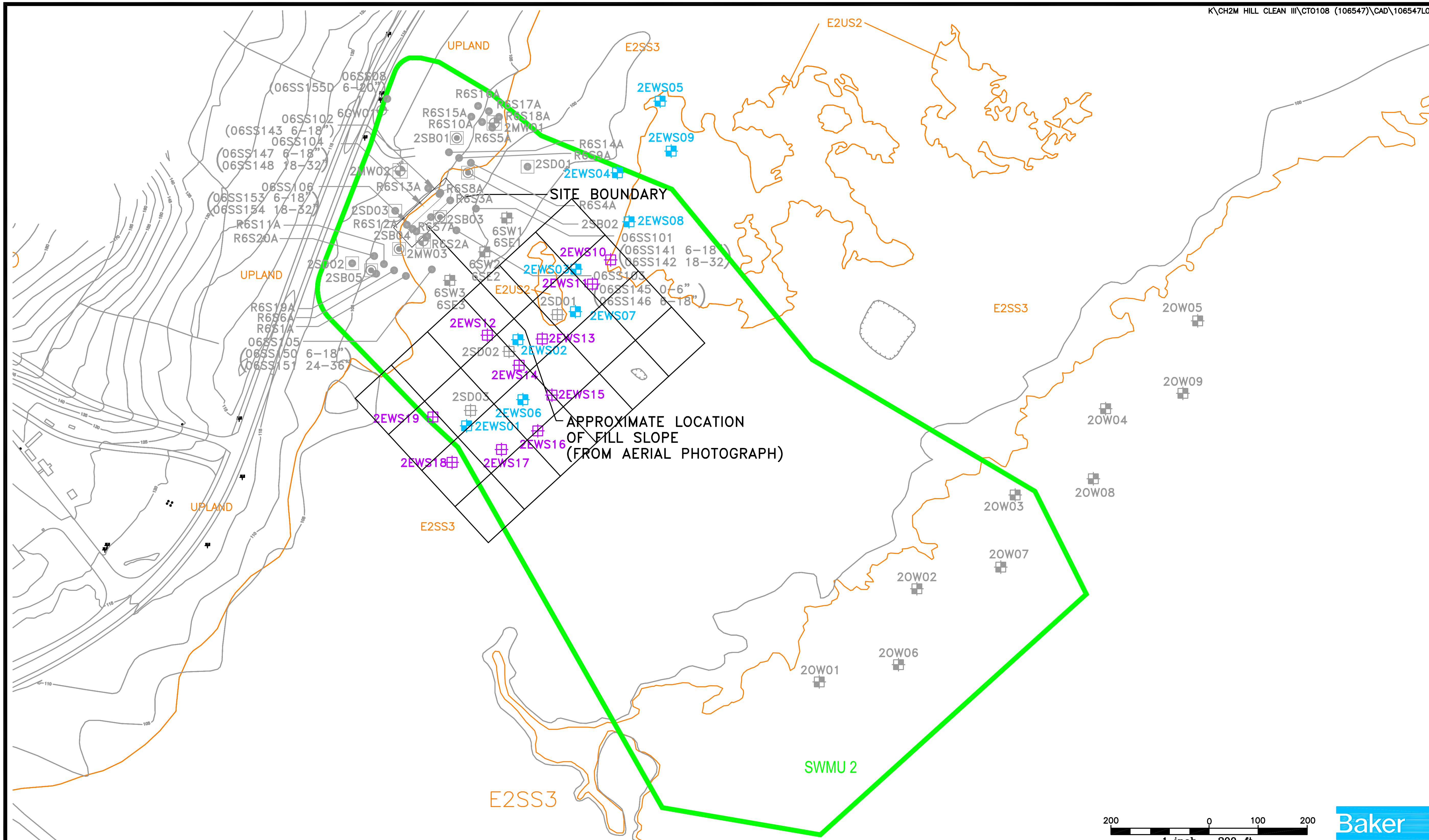
SOURCE: GEO–MARINE, INC., SEPTEMBER 6, 2000.

120 0 60 120
1 inch = 120 ft.

Baker

FIGURE 5–4
PROPOSED SURFACE AND SUBSURFACE SOIL SAMPLING LOCATIONS SWMU 2

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



LEGEND

- SWMU
- E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)

ESTUARINE WETLAND SYSTEM 2003

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)
- SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

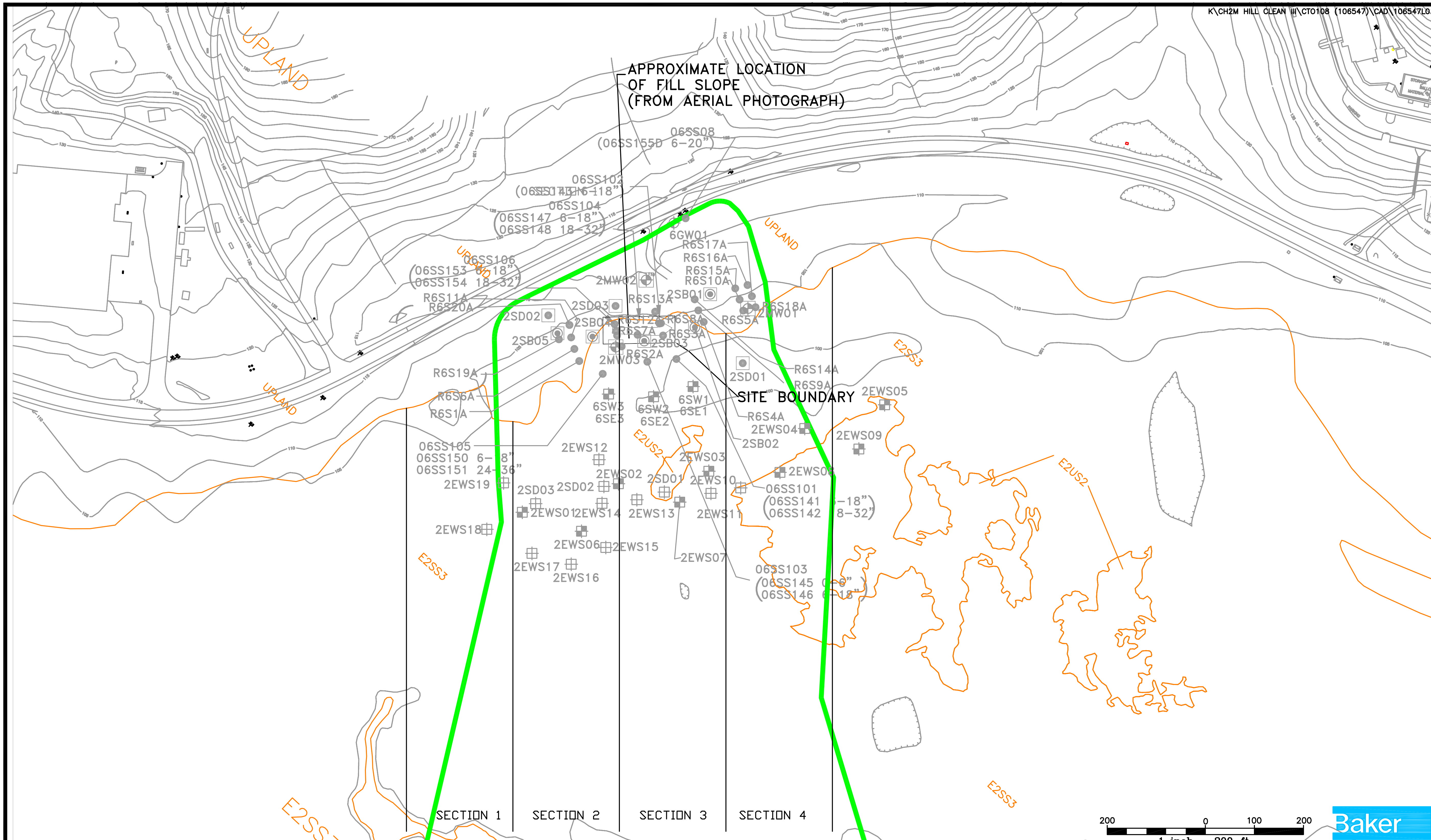
OPEN WATER MARINE 2004

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

FIGURE 5-5
PROPOSED ESTUARINE WETLAND SEDIMENT SAMPLING LOCATIONS SWMU 2

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO



LEGEND

- SWMU
- E2SS3 WETLANDS BOUNDARIES (SEE FIGURE 4-4 FOR CLASSIFICATIONS)
- SURFACE SOIL SAMPLE LOCATION (1996 RFI)
- SEDIMENT SAMPLE LOCATION (RELATIVE RISK RANKING)

SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (CONFIRMATION STUDY)
- SOIL SAMPLE LOCATION (APPROXIMATE) (SUPPLEMENTAL INVESTIGATION)
- SOIL BORING LOCATION (1996 RFI)
- SOIL SAMPLE LOCATION (APPROXIMATE) (CONFIRMATION STUDY)
- MONITOR WELL LOCATION (1996 RFI)
- EXISTING MONITOR WELL LOCATION (CONFIRMATION STUDY)

ESTUARINE WETLAND SYSTEM 2003

- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)
- SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION EFFORT)

OPEN WATER MARINE 2004

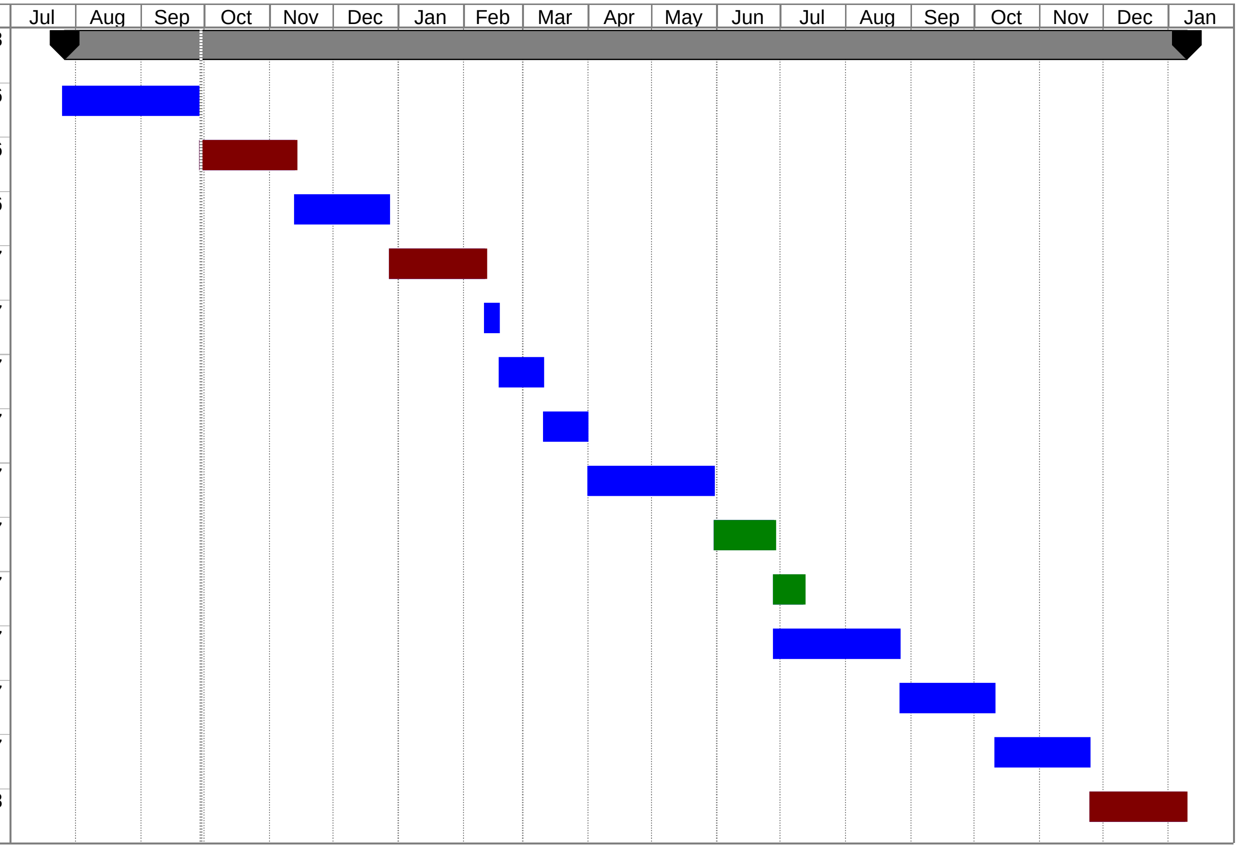
- SURFACE WATER/SEDIMENT SAMPLE LOCATION (ADDITIONAL DATA COLLECTION INVESTIGATION)

FIGURE 5-6
PROPOSED FIDDLER CRAB SAMPLING LOCATIONS SWMU 2

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

FIGURE 6-1
ECOLOGICAL RISK ASSESSMENT SCHEDULE AT SWMUs 1 and 2
NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

Task Name	Duration	Start	Finish
SWMUs 1 and 2	532 edays	7/26/06	1/9/08
Draft Step 3b/4 ERA	65 edays	7/26/06	9/29/06
EPA Review	45 edays	9/29/06	11/13/06
Final Step 3b/4 ERA	45 edays	11/13/06	12/28/06
EPA Review and Approval	45 edays	12/28/06	2/11/07
Field Verification	7 edays	2/11/07	2/18/07
Data Evaluation	21 edays	2/18/07	3/11/07
Work Plan Revision	21 edays	3/11/07	4/1/07
BERA Field Data Collection	60 edays	4/1/07	5/31/07
Laboratory Analysis	28 edays	5/31/07	6/28/07
Data Validation	14 edays	6/28/07	7/12/07
Draft Step 7 Document	60 edays	6/28/07	8/27/07
EPA Review	45 edays	8/27/07	10/11/07
Final Step 7 Document	45 edays	10/11/07	11/25/07
EPA Review and Approval	45 edays	11/25/07	1/9/08



Project: ERA schedule-SWMUs1-2
Date: 9/29/06

Baker/Navy Activity (blue)
Laboratory/Validator Activity (green)
EPA Activity (dark red)

Appendix A:
Data Collection Quality Assurance Plan Addendum

DRAFT

DATA COLLECTION QUALITY ASSURANCE PLAN ADDENDUM

STEP 3B AND 4 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT

SWMU 1 – ARMY CREMATOR DISPOSAL SITE AND SWMU 2 – LANGLEY DRIVE DISPOSAL SITE

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

CONTRACT TASK ORDER 0108

SEPTEMBER 29, 2006

Prepared For:

DEPARTMENT OF THE NAVY
NAVAL FACILITIES
ENGINEERING COMMAND
ATLANTIC DIVISION
Norfolk, Virginia

Under the:

LANTDIV CLEAN Program
Contract N62470-02-D-3052

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

CH2M Hill
Herndon, Virginia

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PREFACE

This Data Collection Quality Assurance Plan (DCQAP) Addendum provides specific quality assurance information for the Estuarine Wetland Baseline Ecological Risk Assessment at Solid Waste Management Unit (SWMU) 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site at Naval Activity Puerto Rico, Ceiba, Puerto Rico. This DCQAP is designed to be used in conjunction with the DCQAP presented within the Final Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for Naval Station Roosevelt Roads, Ceiba, Puerto Rico (Baker Environmental, Inc. [Baker], 1995). General information that is required for this DCQAP can be found within the Final RFI mentioned above. Site personnel are required to review the information presented in both the DCQAP presented in the Final RFI (Baker, 1995), as well as this DCQAP Addendum prior to conducting field activities.

* Italicized print indicates that information in that section is presented in the Master QAPP and not in this QAPP Addendum.

6.0 PROJECT DESCRIPTION AND ORGANIZATION

Solid Waste Management Unit (SWMU) 1 is located within the property boundary of Naval Activity Puerto Rico (NAPR), and encompasses an area of approximately 116 acres. SWMU 1 is comprised of the primary unlined landfill for the base, which operated from the early 1940s through the early 1960s. This facility was included as a Solid Waste Management Unit (SWMU) in the Resource Conservation and Recovery Act (RCRA) Part B Permit (United States Environmental Protection Agency [USEPA], 1994) since preliminary sampling events indicated the presence of contaminants in surface water, sediment, and groundwater.

Previous reports indicate that SWMU 1– former Army Cremator Disposal Site operated from the early 1940s through the early 1960s. Waste disposed at the property included scrap metal, inert ordnance, batteries, tires, appliances, cars, cables, dry cleaning solvent cans, paint cans, gas cylinders, construction debris, dead animals, and residential waste. An Initial Assessment Study (IAS) conducted in 1984 estimated that as much as 1,000 tons of hazardous material could be present at this SWMU.

SWMU 2 – former Langley Drive Disposal Site is located along Langley Drive approximately 1,000 feet northeast of the Navy Commissary and encompasses an area of roughly 28 acres. This SWMU operated as a landfill from approximately 1939 through 1959 and is documented as having been used for the disposal of both hazardous and non-hazardous wastes. The former Langley Drive Disposal Site was included in the Part B Permit since preliminary sampling events indicated the presence of metal contamination in soil, surface water and groundwater.

Site Debris noted during the IAS at SWMU 2 included partially buried metal and concrete objects, old fuel lines, flexible metal hoses, sample containers containing pellets, steel cables, hardened tar, rubble, and ten to fifteen 55-gallon drums that were corroded. The drum contents, generally consisting of a whitish solid with a green outer crust, were exposed (NEESA, 1984). The IAS team estimated the volume of disposed waste to be approximately 1,700 cubic yards, of which approximately 20,000 pounds could be hazardous.

The RCRA Facility Investigation (RFI) conducted at the sites indicated that various environmental media were impacted by past site operations. The additional data collection field investigation was designed to fill identified data gaps necessary to select corrective measures to mitigate human health and ecological risks associated with contamination related to site operations as presented in the Draft Additional Data Collection Work Plan (Baker, 2001). The work plan was written and submitted based on recommendations made in the Revised Draft RFI Report for Operable Unit (OU) 3/5 (Baker, 1999), as well as concurrence of these recommendations by the USEPA.

Since the contaminants of concern and the affected media at SWMU 1 were similar to SWMU 2, the sites were combined into a single Corrective Measures Study Work Plan and a single Ecological Risk Assessment. As part of the Step 3b and 4 of the Baseline Ecological Risk Assessment at SWMUs 1 and 2 (Baker, 2006), collection and analysis of surface soil, subsurface soil, sediment, and fiddler crab and seagrass tissue samples will be conducted. The specific samples and analyses are presented in the Field Sampling and Analysis Plan (FSAP) portion of the report mentioned above.

The objective of this project is to define the requirements necessary to implement the Steps 3b and 4 of the Baseline Ecological Risk Assessment at SWMU 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site, and to complete the necessary sampling and reporting which will document the estuarine wetland ecological risk assessment activities.

Baker's primary participants for this project include:

- Mr. John W. Mentz, Baker – Program Manager
- Mr. Mark E. Kimes, P.E., Baker – NAPR Activity Manager/Project Manager
- Mr. John Malinowski, Baker – Senior Ecological Risk Specialist/QA/QC/Field Team Leader
- Ms. Mary Smith, Baker – Ecological Risk Specialist/Environmental Scientist/Site Health and Safety Officer
- Mrs. Heather Govenor Wojdak, Baker – Ecological Risk Specialist/Environmental Scientist
- Mr. Pete Monday, Baker – Site Manager/Environmental Scientist

Mr. Kimes will be responsible for monitoring the budget and schedule of individual tasks and will have the overall responsibility of completing the work plan, overseeing field activities, and completing the reports for this project. Mr. Malinowski will be technically responsible for ecological risk assessments, with technical input from both Ms. Smith and Mrs. Wojdak. He will also assume the responsibility of team leader while in the field. Mr. Monday will serve as the Site Manager. Ms. Smith will serve as the Site Health and Safety Officer. Geologists, engineers, scientists, biologists, and clerical personnel will support the primary participants as needed.

Overall Quality Assurance/Quality Control (QA/QC) will be the responsibility of Mr. Kimes, while providing senior consulting support and coordination of subcontractor procurement for the project.

Subcontractors will be used to perform laboratory analysis, and data validation. Specific subcontractors have not yet been identified. Baker will perform this investigation with support from the Navy and NAPR.

References:

Baker Environmental, Inc. (Baker), 2006. Final Additional Data Collection Report and Screening Level Ecological Risk Assessment and Step 3A of the Baseline Ecological Risk Assessment for SWMU 1 and SWMU 2, Naval Activity Puerto Rico, Ceiba, Puerto Rico. Coraopolis, Pennsylvania. 2006.

Baker. 2001. Draft Additional Data Collection Work Plan in Support of Ecological Risk Assessment at SWMU 1 and SWMU 2, Naval Station Roosevelt Roads, Ceriba, Puerto Rico. Coraopolis, Pennsylvania. August 10, 2001.

Baker. 1999. Revised Draft RCRA Facility Investigation Report for Operable Unit 3/5, Naval Station, Roosevelt Roads, Puerto Rico. Coraopolis, Pennsylvania. April 1, 1999.

Baker, 1995. Final RCRA Facility Investigation, Naval Station Roosevelt Roads, Ceiba, Puerto Rico. Coraopolis, Pennsylvania. September 14, 1995.

Naval Energy and Environmental Support Activity (NEESA). 1984. Initial Assessment Study of Naval Station Roosevelt Roads, Puerto Rico. NEESA 13-051.

U. S. Environmental Protection Agency, (USEPA). 1994. Notice of Issuance of a Final Resource Conservation and Recovery Act as Amended by the Hazardous and Solid Waste Amendments of 1984 Permit to U.S. Naval Station Roosevelt Roads Ceiba, Puerto Rico. October 20, 1994.

Appendix B:
Health and Safety Plan Addendum

DRAFT

HEALTH AND SAFETY PLAN ADDENDUM

STEPS 3B AND 4 OF THE
BASELINE ECOLOGICAL RISK ASSESSMENT
SWMU 1 – ARMY CREMATOR DISPOSAL SITE
AND
SWMU 2 – LANGLEY DRIVE DISPOSAL SITE

NAVAL ACTIVITY PUERTO RICO
CEIBA, PUERTO RICO

CONTRACT TASK ORDER 0108

SEPTEMBER 29, 2006

Prepared For:

DEPARTMENT OF THE NAVY
NAVAL FACILITIES
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Norfolk, Virginia

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CH2M Hill
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EXECUTIVE SUMMARY

Solid Waste Management Unit (SWMU) 1 encompasses approximately 116 acres of land at Naval Activity Puerto Rico (NAPR), and was the main landfill for the base. SWMU 1, the former Army Cremator Disposal Site, is bounded to the north by Kearsage Road leading to the U.S. Customs Pier, Ensenada Honda to the east, estuarine wetlands to the south, and the Navy Lodge and Bowling Alley to the west. The former Army Cremator Disposal Site was included in the RCRA Part B Permit since an estimated 100,000 tons of waste was disposed of into its unlined waste pile and preliminary sampling events indicated the presence of contaminants in surface water, sediment, and groundwater.

Previous reports indicate that the former Army Cremator Disposal Site operated from the early 1940s through the early 1960s. Waste disposed at the property included scrap metal, inert ordnance, batteries, tires, appliances, cars, cables, dry cleaning solvent cans, paint cans, gas cylinders, construction debris, dead animals, and residential waste. An Initial Assessment Study (IAS) conducted in 1984 estimated that as much as 1,000 tons of hazardous material could be present at this SWMU.

SWMU 2 consists of approximately 28 acres of land at NAPR, and is located along Langley Drive approximately 1,000 feet northeast of the Navy Commissary. The SWMU extends from Langley Drive to the estuarine wetland system, and has a length of 1,300 feet in a northeast-southeast direction. The former Langley Drive Disposal Site was included in the Part B Permit since it was operated as a landfill and included the disposal of hazardous and non-hazardous wastes.

The former Langley Drive Disposal Site was operated as a landfill from approximately 1939 through 1959. Wastes disposed at this unlined landfill included metal and concrete objects, old fuel lines, flexible metal hoses, sample containers containing pellets, steel cables, hardened tar, rubble, and 55-gallon drums. An IAS estimated an approximate 20,000 pounds of hazardous waste could be included in the approximately 1,700 cubic yards of waste disposed of at SWMU 2 - the former Langley Drive Disposal Site.

The chemical exposure potential for personnel working at SWMU 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site at NAPR is expected to be similar to the chemicals identified by analytical analyses from previous sampling investigations at similar sites. The physical hazards that are potential concerns for work to be conducted at SWMUs 1 and 2 are thermal stress and fall hazards. The environmental hazardous include potentially hazardous flora and fauna at NAPR.

The chemical and physical/environmental hazards associated with the tasks to be conducted at SWMU 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site include:

<u>Task 1 – Surface and Subsurface Soil Sampling</u>

Chemical

- Potential for contaminated material to be wiped or blown onto body or in eyes.
- Potential for ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the surface or subsurface soils.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with soil auger or spoons.

- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

Task 2 – Sediment Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Potential for ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the surface or subsurface soils.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with sediment corer, petite ponar dredge, or stainless steel spoons
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects, animals, and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

Task 3 – Seagrass Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the sediments or surface water.
- Absorption of constituents through the skin.

Physical/Environmental

- Potential of cutting skin while collecting above-ground plant material.
- Muscle strain from shoveling or raking to collect whole-plant samples.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects, animals, and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

Task 4 – Fiddler Crab Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the sediments or surface water.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with hand auger.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

Task 5 – Surveying through a GPS Unit

Chemical

- Absorption of constituents through the skin.
- Ingestion of contaminated material from hand-to-mouth contact.

Physical/Environmental

- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral animal life.

Levels of protection outlined in Section 6.0 were selected based on site-specific and task-specific hazard identification, information obtained from previous investigations and site visits, and previous experience with similar investigations or activities.

Also included within this addendum are current emergency procedures, emergency telephone numbers, and hospital route.

2.0 PROJECT PERSONNEL AND RESPONSIBILITIES

The following personnel are designated to carry out the stated job functions for both project and site activities (Note: One person may carry out more than one job function; personnel identified are subject to change). The responsibilities that correspond with each job function are outlined below.

PROJECT MANAGER: Mark Kimes, P.E.

The project manager will be responsible for assuring that all activities are conducted in accordance with the HASP. The Project Manager has the authority to suspend field activities if employees are in danger of injury or exposure to harmful agents. In addition, the Project Manager is responsible for:

- Assisting the Project Health and Safety Officer (PHSO), as designated below, in Site-Specific HASP development for all phases of the project.

- Designating a SHSO and other site personnel who will assure compliance with the HASP.

- Reviewing and approving the information presented in this HASP.

PROJECT HEALTH AND SAFETY OFFICER: Warren Lehew, CIH, CSP

The PHSO will be responsible for general development of the HASP and will be the primary contact for inquiries as to the contents of the HASP. The PHSO will be consulted before changes to the HASP can be approved or implemented. The PHSO will also:

- Develop new protocols or modify the HASP as appropriate and issue amendments.

- Resolve issues that arise in the field with respect to interpretation or implementation of the HASP.

- Monitor the field program through a regular review of field health and safety records, on-site activity audits, or a combination of both.

- Determine that all Baker personnel have received the required training and medical surveillance prior to entry onto a site.

- Coordinate the review, evaluation, and approval of the HASP.

SITE MANAGER: Pete Monday

The Site Manager will be responsible for assuring that all day-to-day activities are conducted in accordance with the HASP. The Site Manager has the immediate authority to suspend field activities if employees are subjected to a situation that can be immediately dangerous to life or health. The Site Manager's responsibilities include:

- Assuring that the appropriate health and safety equipment and personal protective equipment (PPE) has arrived on site and that it is properly maintained.

- Coordinating overall site access and security measures, including documenting all personnel arriving or departing the site (e.g., name, company and time).
- Approving all on site activities, and coordinating site safety and health issues with the SHSO.

- Assisting the SHSO in coordinating emergency procedures with the Naval Activity, emergency medical responders, etc., prior to or during site mobilization activities.

- Assuring compliance with site sanitation procedures and site precautions.

- Coordinating activities with Baker and subcontractor personnel.

- Overseeing the decontamination of field sampling equipment.

- Assuming the responsibilities as indicated under "Field Team Leader," in their absence.

SITE HEALTH AND SAFETY OFFICER: <u>Mary Smith</u>

The SHSO will be responsible for the on-site implementation of the HASP. The SHSO also has the immediate authority to suspend field activities if the health or safety of site personnel is endangered, and to audit the subcontractor training, fit testing, and medical surveillance records to verify compliance. These records will be maintained at the Baker Command Post. The SHSO will also:

- Coordinate the pre-entry briefing and subsequent briefings.

- Assure that monitoring equipment is properly calibrated and properly operated.

- Assure compliance with the Standard Operating Procedures (SOPs) in Attachment A.

- Inform personnel of the material safety data sheets (MSDSs) located in Attachments B and C and emergency procedures for exposure to hazardous materials/waste presented in Attachment D.

- Manage health and safety equipment, including instruments, respirators, PPE, etc., that is used during field activities.

- Confirm emergency response provisions, as necessary, in cooperation with Naval Activity, emergency medical care, etc., prior to or during site mobilization activities.

- Monitor conditions during field activities to ensure worker compliance with the HASP and evaluate if more stringent procedures or a higher level of PPE should be implemented, and informing the PHSO and Project Manager.

- Document, as necessary, pertinent information such as accident investigation and reporting, designated safety inspections, a record of site conditions, personnel involved in field activities, and any other relevant health and safety issues. This information will become part of the official site records.

- Oversee the decontamination of personnel and determine safe boundary procedures for activities requiring Level C or higher protection levels.

- Act as the Emergency Coordinator.

FIELD TEAM LEADER: <u>Pete Monday</u>

The Field Team Leader will be responsible for:

- Safety issues relevant to the tasks under their direction.
- Determining safe boundary procedures for activities requiring Level D or D+ protection levels.
- Assuring that PPE is properly maintained.
- Complying with the conditions as outlined under Field Team Members.
- Assuming the responsibilities as indicated under "Site Manager" in their absence.

SUBCONTRACTOR COMPANIES:

Analytical Services: (To Be Determined)

NAVY BRAC PMO SE REPRESENTATIVES:
Mr. Mark E. Davidson (843) 820-5526

ACTIVITY/STATION/BASE REPRESENTATIVES:
Mr. Pedro Ruiz, Public Works Environmental Eng. Div. (787) 865-4429

FEDERAL/STATE/LOCAL REPRESENTATIVES:
Not assigned

3.2 Facility HASP Objective

This "Facility" Health and Safety Plan (HASP) addresses the ecological investigation that is required at SWMU 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site, with a detailed description of the sites in the section that follows.

3.3 Description of SWMUs 1 and 2

SWMU 1 encompasses approximately 116 acres of land at NAPR, and was the main landfill for the base. The former Army Cremator Disposal Site was included in the RCRA Part B Permit since an estimated 100,000 tons of waste was disposed of into its unlined waste pile and preliminary sampling events indicated the presence of contaminants in surface water, sediment, and groundwater.

Previous reports indicate that SWMU 1, the former Army Cremator Disposal Site, operated from the early 1940s through the early 1960s. Waste disposed into the unlined landfill included scrap metal, inert ordnance, batteries, tires, appliances, cars, cables, dry cleaning solvent cans, paint cans, gas cylinders, construction debris, dead animals, and residential waste. An Initial Assessment Study (IAS) conducted in 1984 estimated that as much as 1,000 tons of hazardous material could be present at this SWMU.

SWMU 2 consists of approximately 28 acres of land at NAPR, and was operated as a landfill which received non-hazardous and hazardous wastes. SWMU 2, the former Langley Drive Disposal Site, was included in the Part B Permit since it was operated as a landfill and included the disposal of hazardous and non-hazardous wastes.

Previous reports indicate that SWMU 2 was operated as a landfill from approximately 1939 through 1959. Wastes disposed at this unlined landfill included metal and concrete objects, old fuel lines, flexible metal hoses, sample containers containing pellets, steel cables, hardened tar, rubble, and 55-gallon drums. An IAS estimated an approximate 20,000 pounds of hazardous waste could be included in the approximately 1,700 cubic yards of waste disposed of at SWMU 2 - the former Langley Drive Disposal Site.

3.4.5 Task-Specific Hazards

Listed below are summaries for the hazards associated with each task for the investigation to be conducted at SWMU 1 – former Army Cremator Disposal Site and SWMU 2 – former Langley Drive Disposal Site. Levels of protection outlined in Section 6.0 were selected based on this task-specific hazard identification, information obtained from previous investigations and site visits, and previous experience with similar investigations or activities.

3.4.5.1 Task 1 – Surface and Subsurface Soil Sampling

Chemical

- Potential for contaminated material to be wiped or blown onto body or in eyes.
- Potential for ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the surface or subsurface soils.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with soil auger or spoons.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

3.4.5.2 Task 2 – Sediment Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Potential for ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the surface or subsurface soils.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with sediment corer, petite ponar dredge, or stainless steel spoons
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects, animals, and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

3.4.5.3 Task 3 – Seagrass Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Ingestion of contaminated material from hand-to-mouth contact.
- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the sediments or surface water.
- Absorption of constituents through the skin.

Physical/Environmental

- Potential of cutting skin while collecting above-ground plant material.
- Muscle strain from shoveling or raking to collect whole-plant samples.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects, animals, and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

3.4.5.4 Task 4 – Fiddler Crab Sampling

Chemical

- Potential for contaminated material to be splashed onto body or in eyes.
- Ingestion of contaminated material from hand-to-mouth contact.

- Inhalation of volatile constituents or volatile fraction of semi-volatile constituents within the sediments or surface water.
- Absorption of constituents through the skin.

Physical/Environmental

- Muscle strain from boring with hand auger.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral (i.e., wild) animal life.

3.4.5.5 Task 5 – Surveying through a GPS Unit

Chemical

- Absorption of constituents through the skin.
- Ingestion of contaminated material from hand-to-mouth contact.

Physical/Environmental

- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and feral animal life.

6.2 Site-Specific Levels of Protection

Based on the information provided in Section 3.0, Site Characterization, the levels of protection and corresponding personal protective equipment have been designated for the following field activities. Upgrading or downgrading the level of protection will be based on real time monitoring, working conditions, and the discretion of the SHSO. Items listed in parentheses are at the discretion of the SHSO, depending on specific site conditions.

Note: No single combination of protective equipment and clothing is capable of protection against all hazards. PPE should be used in conjunction with safe work practices, effective decontamination, and good personal hygiene.

Field Activity	Level of Protection					PPE (Item No.)
	B	C	D +	D	Other	
Surface and Subsurface Soil Sampling				X		4,13, 18, 20,
Sediment Sampling				X		4, 13, 20, 25
Seagrass Tissue Sampling				X		4, 13, 20, 25
Fiddler Crab Tissue Sampling				X		4, 13, 18, 20, 25
GPS Surveying				X		4

EXCEPT IN EMERGENCY SITUATIONS, CHANGES TO THE SPECIFIED LEVELS OF PROTECTION SHALL ONLY BE MADE WITH THE APPROVAL OF THE SHSO AND THE SITE MANAGER, IN CONSULTATION WITH THE PHSO AND PROJECT MANAGER.

8.6 Emergency Hospital Route

An emergency hospital route map (Figure 8-2) showing the location of the local hospital will be posted in the Baker Field Trailer and maintained in the Baker Field Vehicle. Personnel will be informed of the location of the map during the pre-entry briefing. Since the Base Hospital is closed, the hospital to be used for this project is Hospital San Pablo Del Este, located at Avenida General Valero #404, in Fajardo. To get to the hospital, exit the base and take Route 3 north to Fajardo. After passing the Del Este Shopping Center, turn right onto Avenida El Conquistador. Turn Right onto Avenida General Valero (Route 194). The hospital will be on your right.

11.0 HEALTH AND SAFETY PLAN APPROVAL

This HASP has been reviewed by the following personnel prior to submission to LANTDIV.

Warren Lehew	PHSO	
Name (print)	Title (print)	Signature
Mark Kimes	Project Manager	
Name (print)	Title (print)	Signature
Pete Monday	Site Manager	
Name (print)	Title (print)	Signature

TABLES

TABLE 9-1

OSHA TRAINING HISTORY OF BAKER PROJECT PERSONNEL*

Personnel	Title/Role	Training Status	
Mark Kimes	• **Project Manager**	• **40-hr. training completed:**	**7/91**
		• **Supervisory training:**	**9/91**
		• **8-hr. refresher completed:**	**5/05**
		• **First Aid Training:**	**4/03**
		• **CPR Training:**	**4/03**
		• **Medical Surveillance:**	**4/06**
Warren Lehew	• **Project Health and Safety Officer**	• **40-hr. training completed:**	**9/99**
		• **8-hr. refresher completed:**	**12/05**
		• **First Aid Training:**	**8/00**
		• **CPR Training:**	**8/00**
		• **Medical Surveillance:**	**8/04**
Pete Monday	• **Site Manager/Site Health and Safety Officer**	• **40-hr. training completed:**	**3/90**
		• **Supervisory training:**	**9/91**
		• **8-hr. refresher completed:**	**5/02**
		• **First Aid Training:**	**8/95**
		• **CPR Training:**	**8/95**
		• **Medical Surveillance:**	**9/06**

*** Training history for contractor personnel will be maintained at the Command Post.**
N/A – Not Applicable

FIGURES

FIGURE 8-1

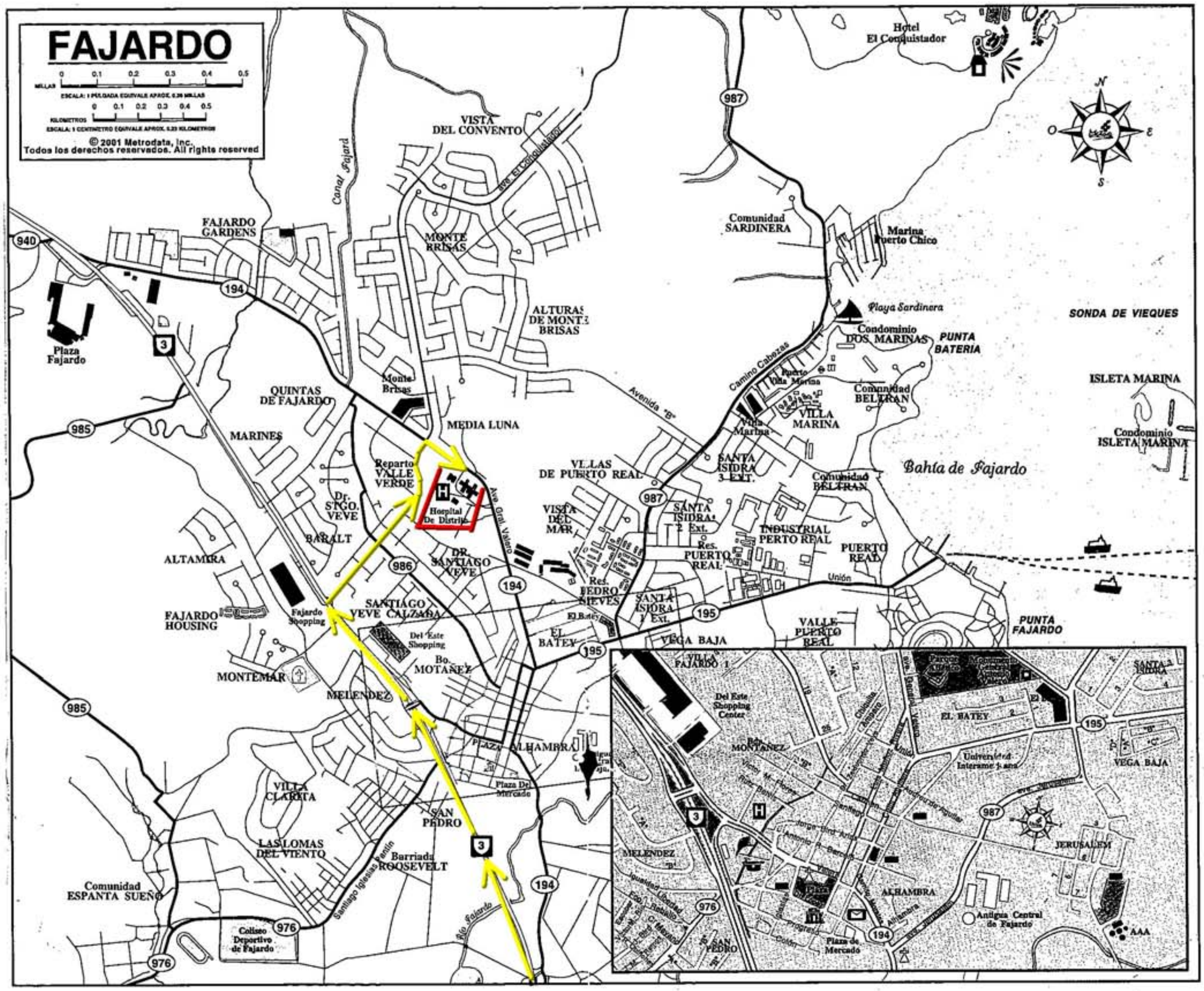
EMERGENCY TELEPHONE NUMBERS

NAPR	Telephone Number On-Base Phone	Telephone Number Off-Base Phone	Contact*
Security (Police)	4108	(787) 865-4106	Response Operator
Fire (On-Scene Commander)	4333	(787) 865-4333	Response Operator
Hospital (Fajardo)	(9) 787-863-0505	(787) 863-0505	Response Operator
General Base Information	2000	(787) 865-2000	Response Operator
Public Works	4159	(787) 865-4159	Mr. Pedro Ruiz
Florida Poison Information Center	(9) 800-222-1222	(800) 222-1222	Response Operator
Federal Maritime Commission	(9) 954-963-5362 (9) 954-963-5284	(954) 963-5362 (954) 963-5284	Andrew Margolis Eric O. Mintz
CHEMTREC	(9) 1-800-424-9300	1-800-424-9300	Response Operator
EPA National Response Center	(9) (800) 424-8802	(800) 424-8802	Response Operator
Baker Project Manager	(9) 412-269-2009	(412) 269-2009	Mr. Mark Kimes
Baker PHSO	(9) 412-269-6068	(412) 269-6068	Mr. Warren Lehew
NAVY BRAC PMO SE	(9) 843-743-2135	(843)-743-2135	Mr. Mark Davidson
USCG Marine Safety Office, Miami	(9) 305-535-8705	(305) 535-8705	Response Operator

* Remaining points of contact will be identified prior to the start of activities.

FIGURE 8-2

HOSPITAL ROUTE



Directions to Hospital San Pablo Del Este:

Exit the base and drive North on Route 3 toward Fajardo. After entering town, you will pass the Del Este Shopping Center on your right. After that, turn right onto Avenida El Conquistador. Proceed approximately 1/2 mile and turn right onto Avenida General Valero. The Hospital will be on your right.

FIGURE 8-3

EMERGENCY MEDICAL SERVICES

Chemical and Nonchemical Exposure Incidents

The nearest hospital is:

Name	Hospital San Pablo Del Este
Address	La Avenida General Valero #404, Fajardo, PR 00738
On-Base Telephone No.	
Off-Base Telephone No.	(787) 863-0505

Local ambulance service is available from:

Name	Hospital San Pablo Del Este
On-Base Telephone No.	
Off-Base Telephone No.	(787) 863-0505

Extreme Emergency

In instances of extreme emergency, or for "stable patient transfer" to nearby public hospitals or those located in the continental United States, contact will be made with Advanced Air Ambulance Service of Miami, Florida. The SHSO and Site Manager will serve as the primary contacts, however, site personnel will be permitted to make contact in extreme emergencies.

Emergency Telephone Numbers: Advanced Air Ambulance
(305) 232-7700 (Miami Headquarters)
(800) 633-3590 (Miami Headquarters)

ATTACHMENT D
Emergency Procedures for Exposure to Hazardous Materials/Waste

ATTACHMENT D

EMERGENCY PROCEDURES FOR EXPOSURE TO HAZARDOUS MATERIALS/WASTE

1. Call ambulance or transport individual to hospital/clinic immediately. Don't forget to take the HASP with you; it contains information on the contaminants expected to be found on site and will assist the physician in his/her assessment of the exposure.

2. Fill in Potential Exposure Report, answering each of the questions to the best of your ability.

3. Contact our physician(s) at EMR as soon as possible. The procedure is as follows:

   a. **Call EMR at 1-800-229-3674**

   b. Ask to speak with:

      Dr. David L. Barnes;
      Dr. Elaine Theriault; or
      Ms. T.J. Wolff, R.N.

Note: During non-business hours (after 6 p.m.) call 1-800-229-3674 and follow directions for paging the aforementioned individuals.

4. Once in contact with any of these individuals, explain what has happened (they will review the information on the form with you and may ask you to fax the form to them, if possible), and allow them to speak with the attending physician.

5. When asked about payment (and they will ask), inform the Hospital/Clinic/Physician that this is a "work related injury" and have them contact Ms. Patty Anderson at (412) 269-4658. Have invoices sent to:

   Michael Baker Jr. Inc.
   Attn: Benefits Coordinator
   Airside Business Park
   100 Airside Drive
   Moon Township, PA 15108

6. Contact the Project Manager and the Project Health and Safety Officer as soon as it is feasible, but wait no longer than 24 hours.

Appendix C:
Habitat Characterization of SWMUs 1, 2, and 45

HABITAT CHARACTERIZATION OF SOLID WASTE MANAGEMENT UNITS (SWMU) 1, SWMU 2, AND SWMU 45, NAVAL STATION ROOSEVELT ROADS, PUERTO RICO

Prepared for:

CH2M Hill

Prepared by:

Dr. Dan L. Wilkinson, Rudi Reinecke, Melissa Lopez-Rodriguez, Manuel Figueroa-Pagan, and Donna DeYoung

Geo-Marine, Inc.
550 E. 15th Street
Plano, Texas 75074

October 11, 2000

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INTRODUCTION

As part of a Resource Conservation and Recovery Act (RCRA) facility investigation at Naval Station (NAVSTA) Roosevelt Roads, Puerto Rico, ecological risk assessments were conducted at 3 solid waste management unit (SWMU) sites. A habitat characterization was conducted at each SWMU in order to determine the presence of plant and animal species and to determine whether preferred habitat was present for any federally endangered or threatened plant and animal species.

SITE LOCATION

NAVSTA Roosevelt Roads (approximately 8,627 acres) is located in the municipality of Ceiba on the southeastern coast of Puerto Rico (Figure 1). This report covers three SWMU sites located at NAVSTA Roosevelt Roads (Figure 2). SWMU 1 and SWMU 2 were located near each other and both had been used as disposal sites and contained similar debris. SWMU 1, an abandoned Army Cremation Disposal Site, is located east of the Navy Lodge with Kearsage Road to the north. Ensenada Honda is to the east and south of SWMU 1, and the Bowling Alley is to the west. SWMU 2 (Langley Drive Disposal Site) is located along Langley Drive and is approximately 2,000 feet northwest of the Navy Exchange. SWMU 2 extends from Langley Drive towards a mangrove community and has an estimated length of 1,300 feet in a northeast-southeast direction. SWMU 45 includes areas outside of Building 38, ground above the cooling water tunnels, and a cove in Puerca Bay. Building 38 is located along a dirt access road south of Forrestal Drive. Associated with Building 38 is a cooling tower intake tunnel that runs from the north end of the building to a small cove in Puerca Bay.

METHODS

Vegetation communities were initially characterized into broad community types based on the color signatures from 1998 true-color and 1993 color infrared (CIR) aerial photographs. Vegetation communities were delineated based on species composition and structure by viewing magnified stereo pairs of aerial photography. The community types were marked on overlying acetate for use in the field (May 15 to 19, 2000). Personnel walked transects through each of these SWMU to:

1. verify that the community types were identified and delineated correctly from the true color and CIR aerial photography;
2. identify the species composition of the dominant vegetation;
3. identify the wildlife species present in the SWMU sites;
4. identify habitat that may potentially support federally designated threatened and endangered species within and contiguous to each SWMU; and
5. identify any obvious impacts potentially related to previous waste management activities.

Figure 1. General Location of NAVSTA Roosevelt Roads, Puerto Rico.

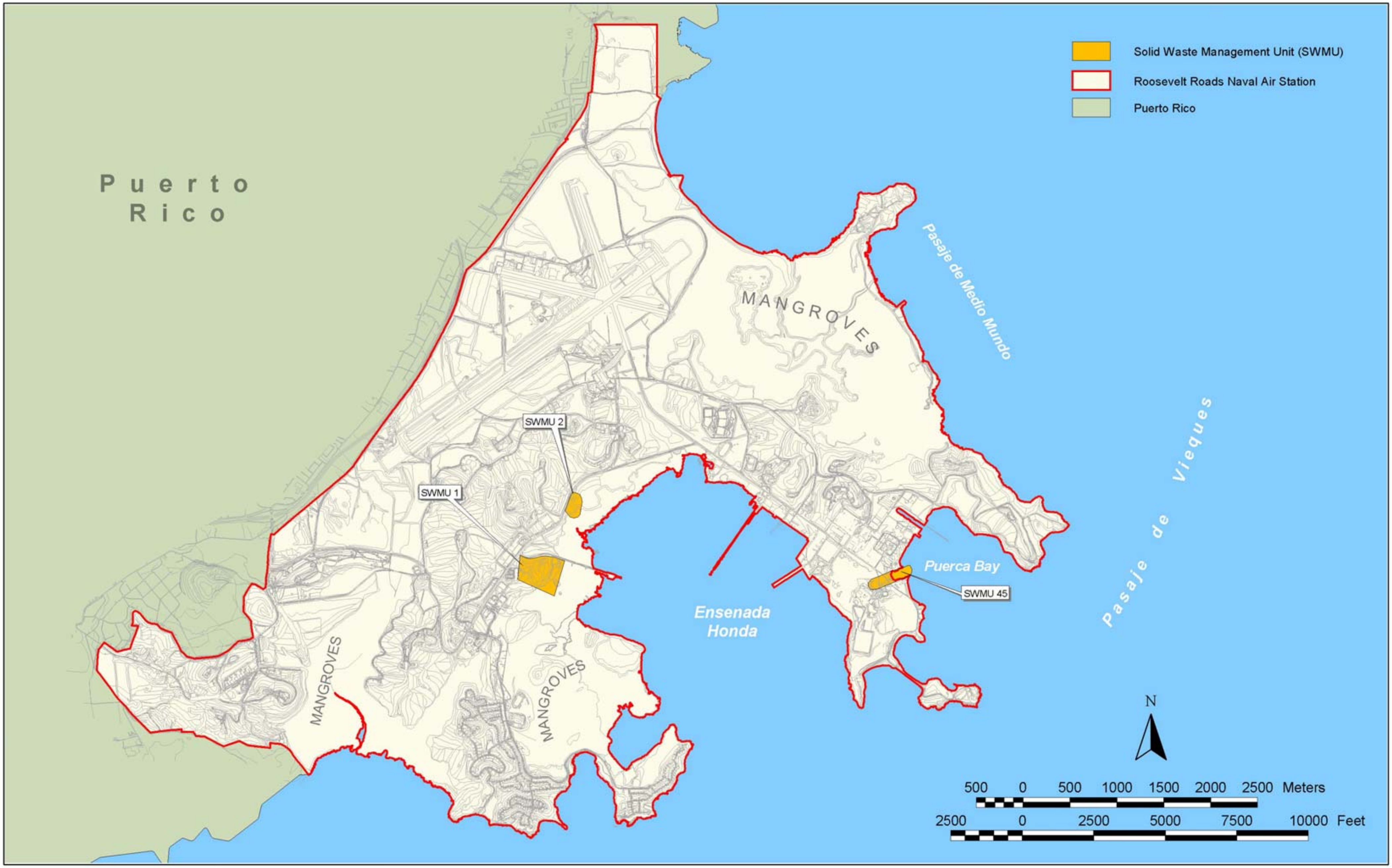

Figure 2. Location of SWMU 1,2 and 45, Roosevelt Roads, Puerto Rico.

The vegetation communities were verified by walking surveys through each community type previously identified with aerial photography. Most species were identified in the field; however, some specimens were collected for identification using reference books (Liogier 1985, 1988, 1994, 1995, 1997; Little and Wadsworth 1964; Little et al. 1964; and Acevedo-Rodriguez 1996) and herbarium specimens. Relative dominance and species structure were characterized from the visual observations within each community type and SWMU.

Wildlife species residing within or utilizing each SWMU habitat, and wildlife habitat were identified during the vegetation field surveys. A wildlife biologist characterized the habitats and determined the types of wildlife that could potentially inhabit the plant communities or SWMU sites. Any wildlife species that were observed were identified in the field with the use of 8 x 40 binoculars and reference guides (Raffaele 1989 and Raffaele et al 1998).

Eleven federally listed species are known to occur or have the potential to occur on NAVSTA Roosevelt Roads (Table 1). The entire NAVSTA Roosevelt Roads was designated as critical habitat in 1976 for the endangered yellow-shouldered blackbird (*Agelaius xanthomus*). However, a 1980 agreement with the USFWS exempted certain areas on the station from this categorization. SWMU 45 is outside this area, while SWMUs 1 and 2 are included within the critical habitat designation.

Prior to conducting the fieldwork, a literature search was conducted for each federally protected species. During the May 15 to 19, 2000 surveys, biologists walked transects through each site and identified any federally protected species seen and noted the presence or absence of preferred habitat for the species.

Table 1

Federally Listed Species Occurring or Potentially Occurring at NAVSTA Roosevelt Roads

***Scientific Name* (Common Name)**	**Federal Status**
Plants	
Stahlia monosperma (Cobana negra)	Threatened
Reptiles and Amphibians	
Caretta caretta (Loggerhead sea turtle)	Threatened
Chelonia mydas (Green sea turtle)	Threatened
Dermochelys coriacea (Leatherback sea turtle)	Endangered
Eretmochelys imbricata (Hawksbill sea turtle)	Endangered
Epicrates inornatus (Puerto Rican Boa)	Endangered
Birds	
Agelaius xanthomus (Yellow-shouldered blackbird)	Endangered
*Falco peregrinus tundrius (*Arctic peregrine)	Threatened
*Pelecanus occidentalis occidentalis (*Brown pelican)	Endangered
Sterna dougalli dougalli (Roseate tern)	Endangered
Mammals	
*Trichechas manatus (*West Indian manatee)	Endangered

Source: U.S. Navy 1998b

Past management activities at the SWMU sites may have potentially impacted the current vegetation communities. During the field surveys the biologists made visual observations to characterize the health of the plants in the SWMU sites. Indications of altered plant communities include; chlorotic leaves, epinasty (deformities of leaves and stems), patches of altered plant growth, absence of plants (bare ground), and changes in species composition. To determine if the SWMU sites contained altered plant communities, a nearby representative site was selected as a control. When altered plant communities were identified, the biologists made an effort to determine and record the probable cause (i.e., chemical, soil compaction, natural causes, etc.).

In addition to identification of wildlife in the field, existing literature sources were used to identify any additional species that may have occurred on the SWMU sites but were not observed. Most of the wildlife occurring in the area is bird species and these are presented in Appendix A. Species information and field data was used to generate a simplified food web for the sites. A food web is an interlocking pattern of several to many food chains that is helpful in determining ecosystem processes including those that may occur when a contaminant is introduced to a system.

A reconnaissance survey of SWMU 45 was conducted June 19, 2000 by Dial Cordy and Associates, Inc. to define the marine habitat and associated flora and fauna of the outfall structure and surrounding embayment and shore. Results are presented in the SWMU 45 section.

RESULTS AND DISCUSSION

SWMU 1

Vegetation Community Description

SWMU 1 (an abandoned Army Cremation Disposal Site) is located east of the Navy Lodge (Figure 3). There were four plant communities identified at this site. Geology and human disturbances, to a lesser extent, have influenced the types of plants occurring at this site. The communities included red mangrove (*Rhizophora mangle*), black mangrove, (*Avicennia germinans*), coastal upland forest, and coastal scrub forest. These communities were identified in the NAVSTA Roosevelt Roads Integrated Natural Resources Management Plan (U.S. Navy 1998b) and brief descriptions follow.

The mangrove communities were located farthest east of the Navy lodge in SWMU 1 and had little evidence of human disturbance. Both red and black mangrove communities had sparse cover consisting of low growing shrubs. The red mangroves occurred adjacent to Ensenada Honda and the community was sparsely vegetated (approximately 25 percent cover) with large pools of water present. Nearly all vegetation included short shrubs of red mangrove and numerous red mangrove seedlings were observed.

The black mangroves were located inland between the red mangroves and the coastal upland forest community. Species composition consisted of saline tolerant plants as the result of periodic saturation with highly saline water. The site had sparse vegetation cover (approximately 25 percent) and plants were predominately short shrubs (8 to 15 feet). In addition, there was some herbaceous vegetation near the inland boundary. Black mangrove trees and shrubs dominated the shrub vegetation. The herbaceous vegetation was dominated by *Batis maritima*, with *Sporobolus virginicus* and *Sesuvium portulacastrum* also present.

An upland coastal forest community was located on the southern portion of the hill to the east of the Navy lodge. The upland coastal forest served as the upland boundary of the black mangrove community. Soil disturbance, debris, and an un-maintained road for access to several monitoring wells were observed. Tree cutting may have occurred in this area in the past; however, relatively large trees were observed. Shrubs with scattered large trees (8 to 14 inches in diameter breast height) and grassy areas dominated the community. There was approximately 80 to 90 percent vegetation cover with multiple layers of stratification. *Leucaena leucocephala*, *Bursera simaruba*, and *Randia aculeata* dominated the shrub layer. *Bucida buceras*, *Trichostigma octandrum*, and *Psidium guajava* were the only trees present, and these were confined to the ridges and steep hillsides. Patches of herbaceous areas were dominated by *Panicum maximum*.

The coastal scrub forest community also showed signs of soil disturbance and had vegetation similar to the upland forest community. However, the coastal scrub had less topographic relief, fewer trees, and larger grassy patches than the upland forest. Vegetation cover in the coastal scrub was approximately 80 to 95 percent and was limited to two stratums (shrub and herbaceous). The lack of tree cover had probably occurred due to slope exposure to hurricane force winds. *Leucaena leucocephala* and *Panicum maximum* dominated the shrub and herbaceous stratums, respectively. Vegetation photos for SWMU 1 are presented in Figures 4 and 5. The vegetation observed at SWMU 1 is presented in Table 2.

Plant Community Health

The control for SWMU 1 was carefully chosen in order to represent the different plant communities present. Factors needed for the control included a protected hillside community adjacent to mangroves and proximity to SWMU 1. The control that was chosen had upland coastal forest, coastal scrub forest, and mangroves similar to SWMU 1 and was located on the south side of Langley Drive between the elementary school and South Princeton Road.

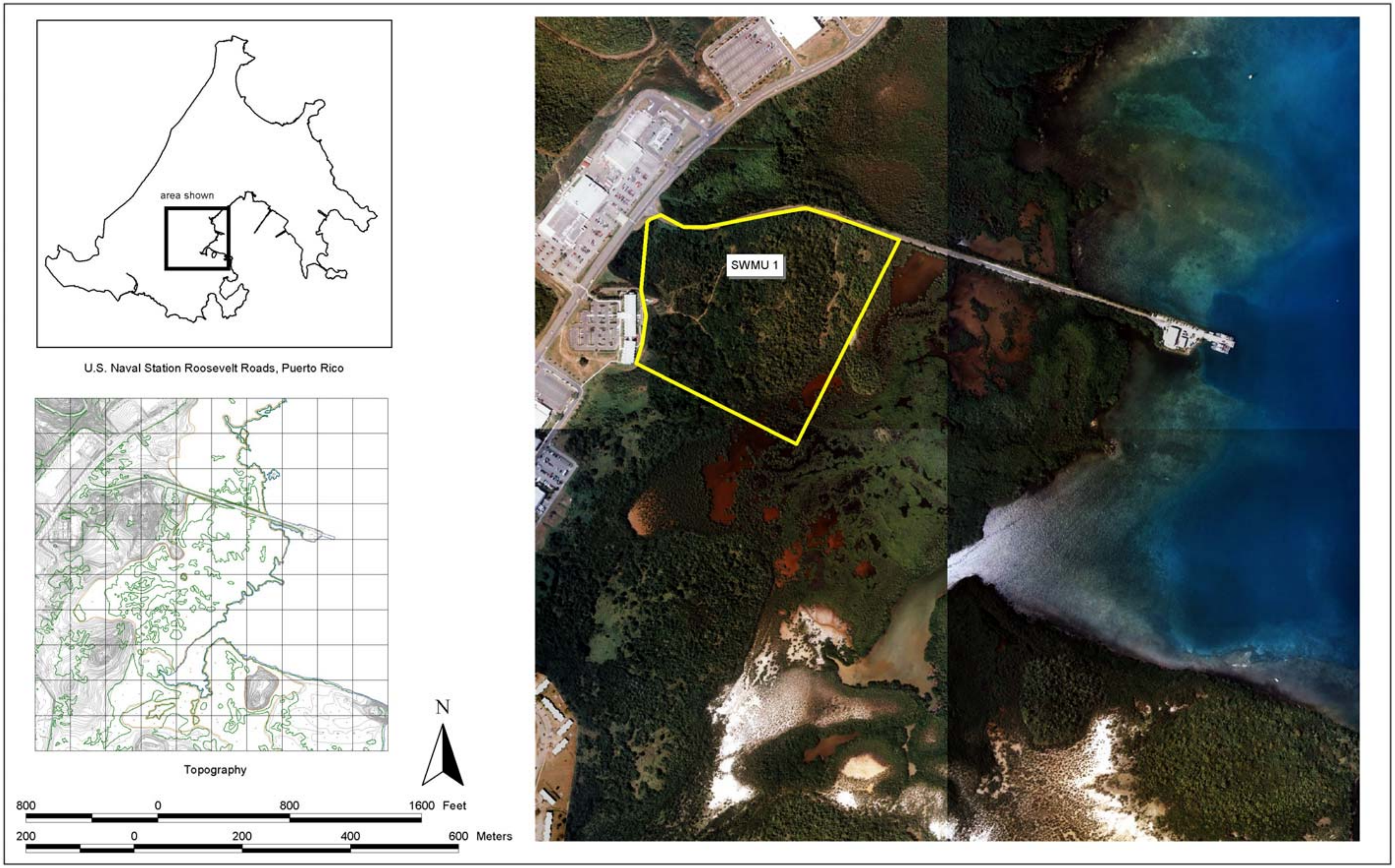

Figure 3. Location of SWMU 1, Roosevelt Roads, Puerto Rico

Figure 4. SWMU 1, Red Mangrove Community (*Rhizophora mangle*) with Upland Coastal Forest in Background.

Figure 5. SWMU 1, Coastal Scrub Forest Community

Table 2

Vegetation Observed at SWMU 1

Common Name	Scientific Name	Stratum
Black Mangrove		
black mangrove	*Avicenia germinans*	S
salt plant, saltwort	*Batis maritima*	H
white mangrove	*Laguncularia racemosa*	S
verdolaga rosada, pink purslane	*Sesuvium portulacastrum*	H
None	*Sporobolus virginicus*	H
Red Mangrove		
red mangrove	*Rhizophora mangle*	S
Upland Coastal Forest		
crab's eye, jumbie bead, rosary bead	*Abrus precatorius*	S
none	*Acacia westiana*	S
none	*Bothriochloa ichaemum*	H
Ucar, oxhorn bucida	*Bucida buceras*	T
almácigo	*Bursera simaruba*	S/T
bottle wiss	*Capparis flexusa*	S
French grass	*Commelina erect*	H
Bermuda grass	*Cynodon dactylon*	H
none	*Ipomea* spp.	V
none	*Lasiacis divaricata*	H
none	*Leptochloa ichaemum*	H
tan tan, tanty, wild tamarind, lead tree	*Leucaena leucocephala*	S
none	*Panicum maximum*	H
guayaba, common guayaba	*Psidium guajava*	T
Christmas tree, tintillo	*Randia aculeata*	S
none	*Sporobolus indicus*	H
none	*Tragia volubilis*	H
basket wiss	*Trichostigma octandrum*	S/T
marsh-mallow	*Waltheria indica*	H
Coastal scrub forest		
none	*Asystasia gangetica*	H
almácigo	*Bursera simaruba*	S
bottle wiss	*Capparis flexusa*	S
none	*Cissus obovata*	V
palma de coco	*Cocos nucifera*	S
rattle box, yellow lupine	*Crotalaria retusa*	H
flamboyant tree, Poinciana	*Delonix regia*	S
brazilette	*Erythroxylum brevipes*	S
none	*Forestiera eggersiana*	S
black mampoo, wild mampoo	*Guapira fragans*	S
none	*Ipomea* spp.	H
tan tan, tanty, wild tamarind, lead tree	*Leucaena leucocephala*	S
cat claw, cat paw, monkey earing	*Macfadyena unguis-cati*	S
none	*Panicum maximum*	H
none	*Pinzona coriacea*	H
Christmas tree, tintillo	*Randia aculeata*	S
royal palm	*Roystonea borinquena*	S
basket wiss, white root, black or white wist	*Serjania polyphylla*	V
basket wiss	*Trichostigma octandrum*	S/T

S = shrub
T = tree
H = herbaceous
V = vine

There were no noticeable differences in plant community species composition between the control and the SWMU 1 site. However, the structure of the plant communities was somewhat different. SWMU 1 had more grassy areas within the coastal scrub forest community than the control. The increase in grassy areas was probably the result of past dirt-moving activities at SWMU 1. There were also more large trees at SWMU 1 in the upland coastal forest community than the control. It appeared that the control hillside had been more exposed to hurricane force winds thus resulting in fewer large trees.

The SWMU 1 plant communities seemed to be growing healthy and vigorously. The mangrove communities had a low vegetation cover; however, depending upon their position in the landscape, this is not uncommon. Debris and evidence of dirt-moving activities were observed in the upland coastal forest and the coastal scrub forest communities, but ecological succession was occurring and the existing forest communities had no evidence of stress.

Wildlife Description

During the short duration of wildlife surveys conducted on this site, numerous wildlife species such as birds and lizards (*Anolis* species) were observed utilizing the habitat of this site. An active Wilson's plover (*Charadrius wilsonia*) nest was found in the black mangrove community. The mangrove communities also had significant crab activity. The red mangrove community, with more water present, had more crab holes than the black mangroves. There was no evidence that the SWMU site had an impact on the wildlife diversity or its habitat. Wildlife that was observed at SWMU 1 is presented in Table 3.

Protected Species

Stahlia monosperma (Cobana negra), a federally threatened tree, has been found between the boundary of black mangrove communities and coastal upland forest communities. This species is also known to occur in coastal forests of southeastern Puerto Rico (Little and Wadsworth 1964). However, this species has not been verified as occurring on NAVSTA Roosevelt Roads by past surveys (U.S. Navy 1998b) and was not observed during the surveys.

The Puerto Rican boa (*Epicrates inornatus*) utilizes a variety of habitats but is most commonly found in karst forest habitats. The coastal upland forest community habitat at SWMU 1 is similar to karst habitat due to the steep topography and presence of large stature trees (an indicator of minimal recent disturbance). Occurrence of the boa at NAVSTA Roosevelt Roads has not been verified and due to the disturbance at SWMU 1, there is a low probability of occurrence for the species at this site.

Table 3

Wildlife Observed at SWMU 1

English Name	Scientific Name	Local Name
Red and Black Mangrove Communities		
Birds		
Green Mango	*Anthracothorax viridis*	Zumbador Verde de P.R.
Red-tailed Hawk	*Buteo jamaicensis*	Guaraguao de Cola Roja
Wilson's Plover	*Charadrius wilsonia*	Playero Marítimo
Yellow Warbler	*Dendroica petechia*	Canario de Mangle
Common Moorhen	*Gallinula chloropus*	Gallareta Común
Ruddy Quail-Dove	*Geotrygon montana*	Perdiz Pequeña
Puerto Rico Woodpecker	*Melanerpes portoricensis*	Carpintero de Puerto Rico
Northern Mockingbird	*Mimus polyglottos*	Ruiseñor
Cave Swallow	*Pterochelidon fulva*	Golondrina de Cuevas
Greater Antillean Grackle	*Quiscalus niger*	Mozambique (Chango)
Louisiana Waterthrush	*Seiurus motacilla*	Pizpita de Rio
Loggerhead Kingbird	*Tyrannus caudifasciatus*	Clérigo
Gray Kingbird	*Tyrannus dominicensis*	Pitirre
Upland Coastal Forest		
Reptiles and Amphibians		
Crested Anole	*Anolis cristatellus*	not known
Birds		
Red-tailed Hawk	*Buteo jamaicensis*	Guaraguao de Cola Roja
Bananaquit	*Coereba flaveola*	Reinita Común
Yellow Warbler	*Dendroica petechia*	Canario de Mangle
Ruddy Quail-Dove	*Geotrygon montana*	Perdiz Pequeña
Pearly-eyed Thrasher	*Margarops fuscatus*	Zorzal Pardo
Northern Mockingbird	*Mimus polyglottos*	Ruiseñor
Greater Antillean Grackle	*Quiscalus niger*	Mozambique (Chango)
Coastal Scrub Forest		
Reptiles and Amphibians		
Brown Lizard	*Anolis cristatellus*	not known
Lizard	*Anolis stratulus*	not known
Birds		
Bananaquit	*Coereba flaveola*	Reinita Común
Ruddy Quail-Dove	*Geotrygon montana*	Perdiz Pequeña
Grackle	*Quiscalus niger*	Mozambique (Chango)
Loggerhead Kingbird	*Tyrannus caudifasciatus*	Clérigo
Gray Kingbird	*Tyrannus dominicensis*	Pitirre
Black-Whiskered Vireo	*Vireo altiloquus*	Bien-te-veo
Zenaida Dove	*Zenaida aurita*	Tórtola cardosantera

Federally threatened and endangered sea turtles such as the Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*) and Leatherback sea turtles (*Dermochelys coriacea*) and the endangered West Indian Manatee (*Trichechas manatus*) would not occur at this site because they require marine habitats. There is potential for some of the species to occur in nearby Ensenada Honda, however most of the site considered here contained terrestrial habitat.

Federally endangered marine birds such as the Brown pelican (*Pelecanus occidentalis occidentalis*) and the Roseate tern (*Sterna dougalli dougallii*) would most likely not occur at this terrestrial site due to the absence of preferred habitat. The Roseate tern has not been observed on or adjacent to the NAVSTA Roosevelt Roads (U.S. Navy 1998b), although it has been observed recently at Vieques Island. Brown pelicans prefer more coastal areas.

Potential upland feeding habitat (shrubland) was present for the yellow-shouldered blackbird (*Agelaius xanthomus*). However, nesting habitat for the species (mature mangroves and Royal Palm [*Roystonea borinquena*]) was not present. Some nesting habitat may have been located adjacent to the site (U.S. Navy 1998a). A pair of yellow-shouldered blackbirds was observed near the site, although only seven sightings in all have been reported at NAVSTA Roosevelt Roads from 1986 to 1996.

The Arctic peregrine falcon (*Falco peregrinus tundrius*) has been observed at NAVSTA Roosevelt Roads (U.S. Navy 1998b). This species utilizes open grassland areas for potential feeding areas. This type of habitat was not present at or near this site.

Food Web

The information in a food web is very important when considering the potential for contaminants existing in the ecosystem. Many contaminants are passed from one trophic level to the next. A contaminant at the soil surface goes through a different process than a contaminant that has leached into the soil. The surface contaminant may be ingested by a decomposer such as a hermit crab and then passed on to the secondary consumer (i.e., a carnivorous bird). Leached contaminates are picked up by the primary producers and are then passed upwards in the food chain.

Figure 6 presents a generalized food web for the upland coastal forest and the coastal scrub forest communities. Figure 7 presents a food web for the mangrove communities. The abundance within each of the food groups is represented by the size of their polygon in the figure. Dominant species are listed in each of the food groups except for plants, which were provided previously in this section.

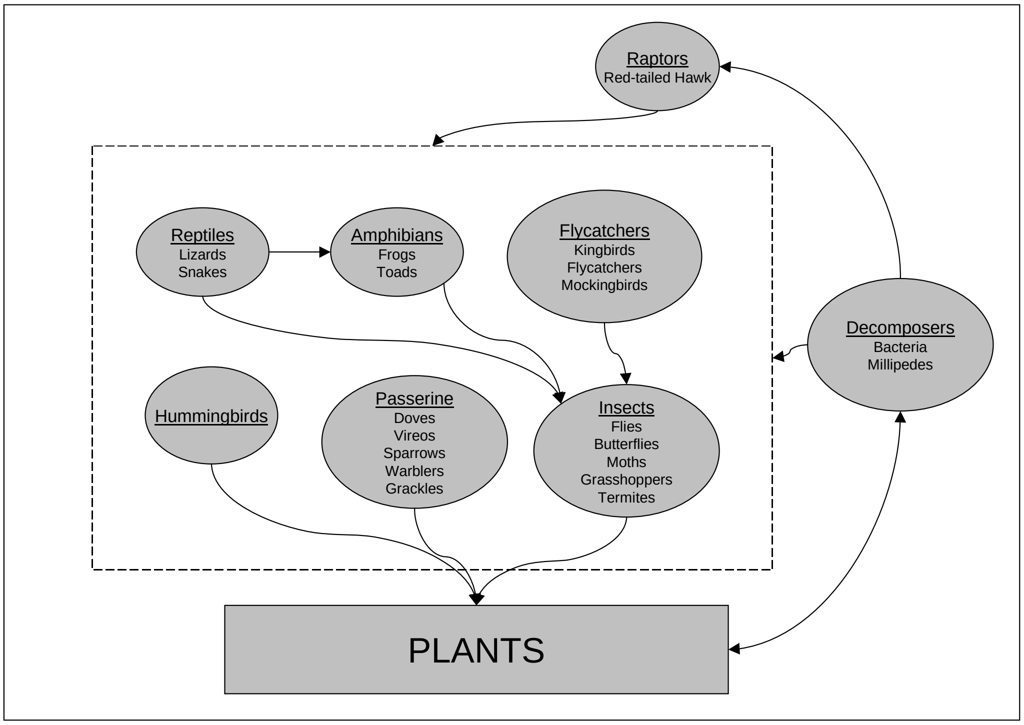

Figure 6. Generalized Food Web for the Upland Coastal Forest and Coastal Scrub Forest Communities at NAVSTA Roosevelt Roads.

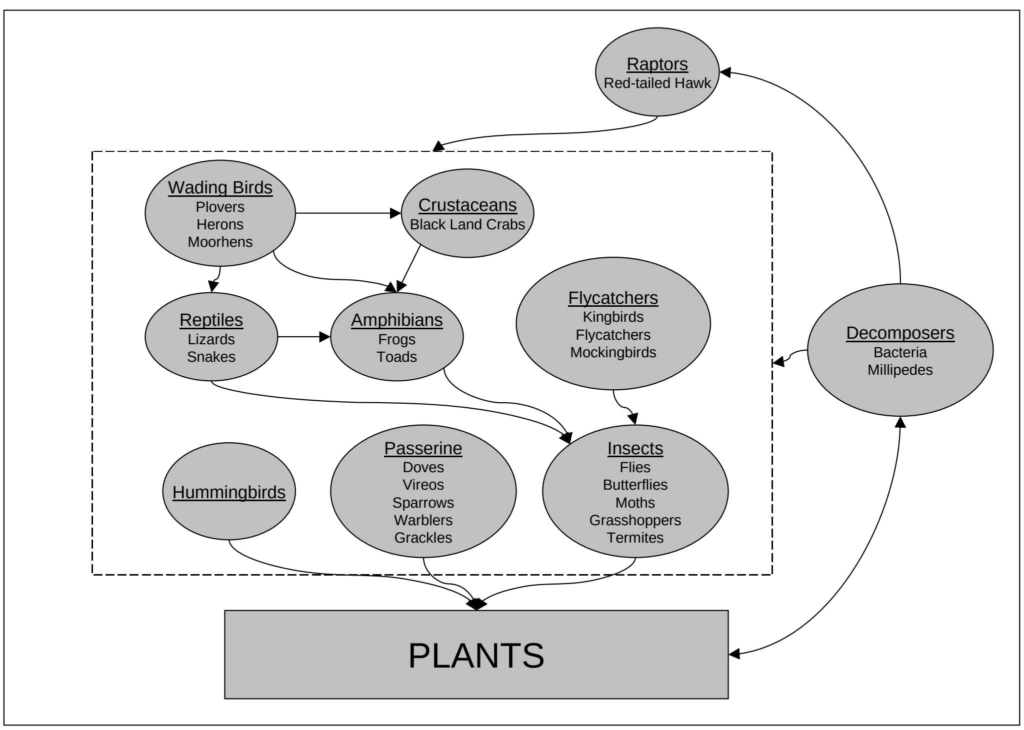

Figure 7. Generalized Food Web for Mangrove Communities at NAVSTA Roosevelt Roads.

SWMU 2

Vegetation Community Description

SWMU 2, Langley Drive Disposal Site, is located along Langley Drive and is approximately 2,000 feet northwest of the Navy Exchange. SWMU 2 extends from Langley Drive in a gentle slope towards a mangrove community and has an estimated length of 1,300 feet in a northeast-southeast direction. Disturbances consisted of an un-maintained road that led to a monitoring well. There was a small earthen berm running parallel to the mangrove boundary. The dominant vegetation was upland coastal forest; however, the adjacent black mangrove community was also described.

Various stages of ecological succession were observed throughout the upland coastal forest community and canopy cover approached 100 percent. The dominant plant community along the monitoring well road was herbaceous vegetation with *Leucaena leucocephala* shrubs, *Panicum maximum*, *Sporobolus indicus*, and *Waltheria indi*ca. Road edges were a nearly monotypic stand of *Leucaena leucocephala* shrubs. Further from the monitoring well road, there were fewer individuals of Leucaena *leucocephala* and more upland coastal forest plant community species such as *Bursera simaruba*, *Erthroxylum brevipes,* and *Capparis flexusa*.

Although the mangrove community was limited within SWMU 2, it is described here and included in Table 4. The mangrove community formed the boundary for SWMU 2 and contained a number of additional species that are not typically found in mangrove communities. Because the area described was in the upland/wetland boundary (ecotone) of the community and there was adjacent road disturbance, higher species richness would be expected. Dominant plants included black mangrove, *Leucaena leucocephala*, and *Randia aculeata*. Vegetation photos are presented in Figures 9 and 10. The vegetation observed at SWMU 2 is presented in Table 4.

Plant Community Health

The control for SWMU was a similar plant community found on the eastern boundary of SWMU 2 along Langley Road. The control had similar topography, soils, position in landscape, and it was located between a paved road and a mangrove community. The only difference between the control and SWMU 2 was that SWMU 2 contained a road that had created an opening in the plant community. This opening had allowed an herbaceous stratum to establish and *Leucaena leucocephala* dominated the road edges. No other vegetation stresses were observed throughout the SWMU 2 community when compared to the control.

Table 4

Vegetation Observed at SWMU 2

Common Name	Scientific Name	Stratum
Upland Coastal Forest		
aroma, sweet acacia	*Acacia farnensiana*	S
none	*Bothriochloa ichaemum*	H
bottle wiss	*Capparis flexusa*	S
none	*Cissus obovata*	V
none	*Ipomea spp.*	V
tan tan, tanty, wild tamarind, zarcilla	*Leucaena leucocephala*	S
none	*Macfadyena unguis-cati*	S
none	*Panicum maximum*	H
cattle tongue, sweet scent	*Pluchea carolinensis*	H
none	*Sporobolus indicus*	H
yerba socialista, socialist herb	*Vernonia cinerea*	H
marsh mallow	*Waltheria indica*	H
Black mangrove		
black mangrove	*Avicenia germinans*	S/T
almácigo, turpentine-tree	*Bursera simaruba*	S/T
bottle wiss	*Capparis flexuosa*	S
Black willie, Jamaican caper	*Capparis cynophallophora*	S/T
brazilette	*Erythroxylum brevipes*	S
none	*Foresteria eggersiana*	S
black mampoo, wild mampoo	*Guapira fragans*	S
none	*Lasiacis divaricata*	H
tan tan, tanty, wild tamarind, lead tree	*Leucaena leucocephala*	S
none	*Panicum maximum*	H
Christmas tree, tintillo	*Randia aculeata*	S
none	*Sporobolus indicus*	H

S = shrub
T = tree
H = herbaceous
V = vine

Wildlife Description

During the short duration of wildlife surveys conducted on this site, numerous wildlife species including birds, lizards, frogs, and crabs were observed utilizing the habitat of this site (Table 5). A large land crab (*Ucar* species) was observed in the mangrove community. There was no evidence that the SWMU site had an impact on the wildlife or its habitat.

Protected Species

SWMU 2 was in close proximity and had similar habitat as SWMU 1. There were no federally protected species or preferred habitat observed at SWMU 2. See the discussion on protected species for SWMU 1 for information on potentially occurring species and their habitat.

Food Web

Figures 6 and 7 present generalized food webs for the upland coastal forest and mangrove communities, respectively.

Table 5

Wildlife Observed at SWMU 2

English Name	Scientific Name	Local Name
Upland Coastal Forest		
Reptiles and Amphibians		
Lizard	*Anolis cristatellus*	not known
Lizard	*Anolis pulchellus*	not known
Frog	*Eleutherodactylus sp.*	not known
Frog	*Leptodactylus albilabris*	not known
Birds		
Red-tailed Hawk	*Buteo jamaicensis*	Guaraguao de Cola Roja
Yellow Warbler	*Dendroica petechia*	Canario de Mangle
Pearly-eyed Thrasher	*Margarops fuscatus*	Zorzal Pardo
Puerto Rico Woodpecker	*Melanerpes portoricensis*	Carpintero de Puerto Rico
Northern Mockingbird	*Mimus polyglottos*	Ruiseñor
Greater Antillean Grackle	*Quiscalus niger*	Mozambique (Chango)
Gray Kingbird	*Tyrannus dominicensis*	Pitirre
Black-Whiskered Vireo	*Vireo altiloquus*	Bien-te-veo
Zenaida Dove	*Zenaida aurita*	Tórtola Cardosantera
Mangrove		
Crustacean		
Land Crab	*Ucar sp.*	Ucar
Birds		
Bananaquit	*Coereba flaveola*	Reinita Común
Loggerhead Kingbird	*Tyrannus caudifasciatus*	Clérigo
Black-Whiskered Vireo	*Vireo altiloquus*	Bien-te-veo
Zenaida Dove	*Zenaida aurita*	Tórtola Cardosantera

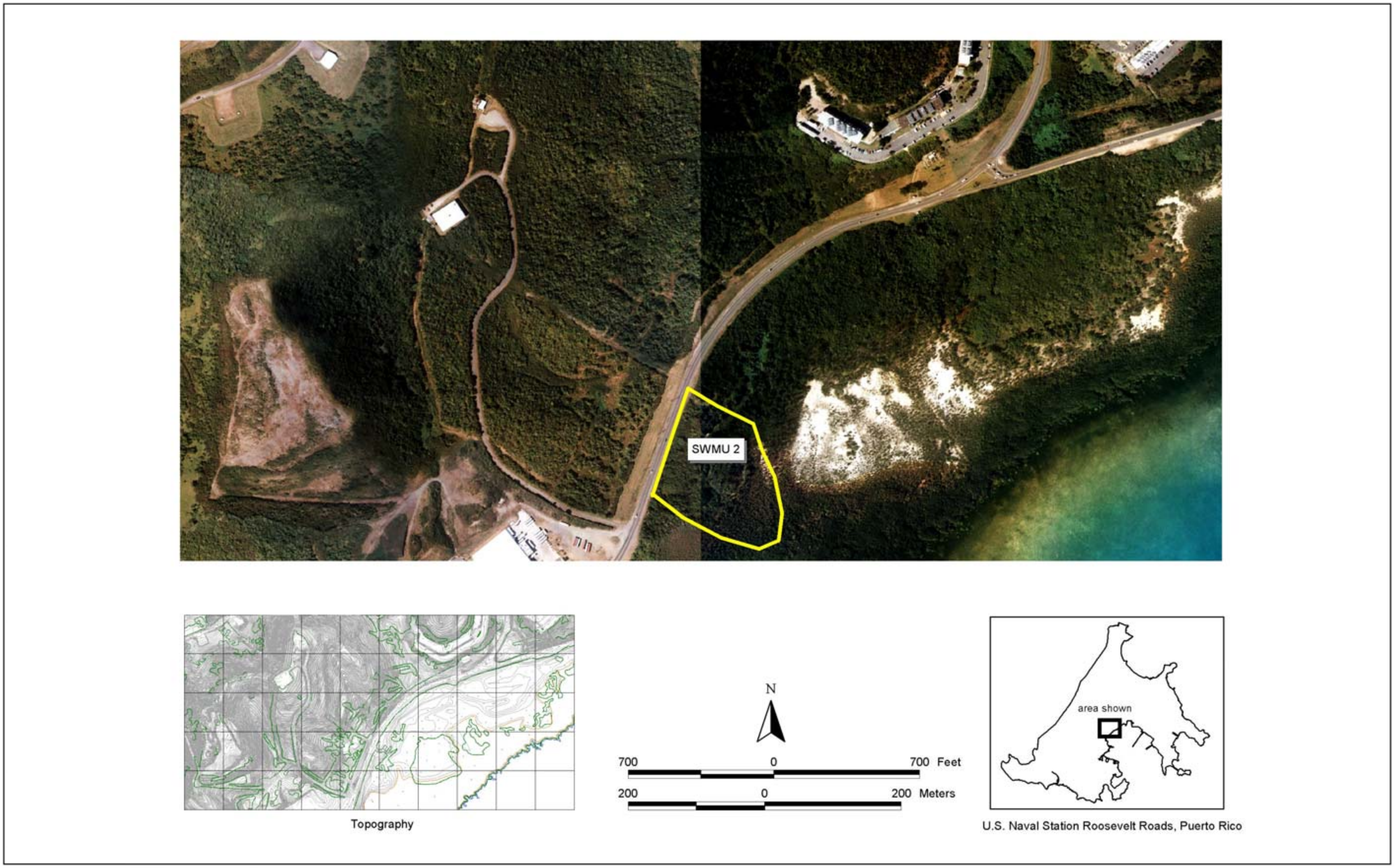

Figure 8. Location of SWMU 2, Roosevelt Roads, Puerto Rico

Figure 9. SWMU 2, Un-maintained Road in Center of Photograph within the Upland Coastal Forest Community.

Figure 10. SWMU 2, Typical Vegetation Showing Upland Coastal Forest Species

SWMU 45

Terrestrial Area

Vegetation Community Description

SWMU 45 included areas outside of Building 38, the right-of-way for the cooling water tunnels, and a small cove in Puerca Bay (Figure 11). Building 38 is located along a dirt access road south of Forrestal Drive. Grounds maintenance and building maintenance activity appeared to have been abandoned a few years ago. NAVSTA Roosevelt Roads INRMP indicated that the general cover type for the terrestrial portion of SWMU is urban/developed (U.S. Navy, 1998b). However, observations of the present species composition indicated that the site was in the early ecological succession stages of an upland coastal forest community. In addition to the vegetation around the building and the cooling water tunnel right-of-way, there was a fringe of mangroves along the cove of Puerca Bay. The marine environment at the small cove within Puerca Bay is discussed later.

The majority of the site was located on nearly level upland terrain with almost 100 percent vegetation cover. Shrubs dominated the site, except where road corridors occurred. Maintained grasses such as *Bothriochloa ischaemum*, *Chloris barbata*, and *Digitaria* sp. dominated the road corridors while 10 to 15-foot tall *Leucaena leucocephala* shrubs dominated the un-maintained areas.

The small cove at Puerca Bay was shallow and had been excavated for the water cooling tunnels. The fringe of the bay had near 100 percent shrub cover and little to no herbaceous vegetation. *Thespesia populnea* shrubs dominated the community. There were also sparse black mangroves, *Stachytarpeta jamaicensis*, and *Heliotropium curassavicum* present. A wildlife photo along the cove shoreline is presented in Figure 12. The vegetation observed at SWMU 45 is presented in Table 6.

Plant Community Health

Because SWMU 45 was very similar to SWMU 2 in species composition, community structure, and topography, the same control plot was used for both sites. The control was located along Langley Road adjacent to the eastern boundary of SWMU 2. There were minimal differences between the control and SWMU 45. Most of SWMU 45 had been well maintained, but it appeared that recent lack of maintenance had allowed *Leucaena leucocephala*, an invasive species, to increase. Besides mowing and other grounds maintenance practices at SWMU 45, there were no other plant community stresses observed.

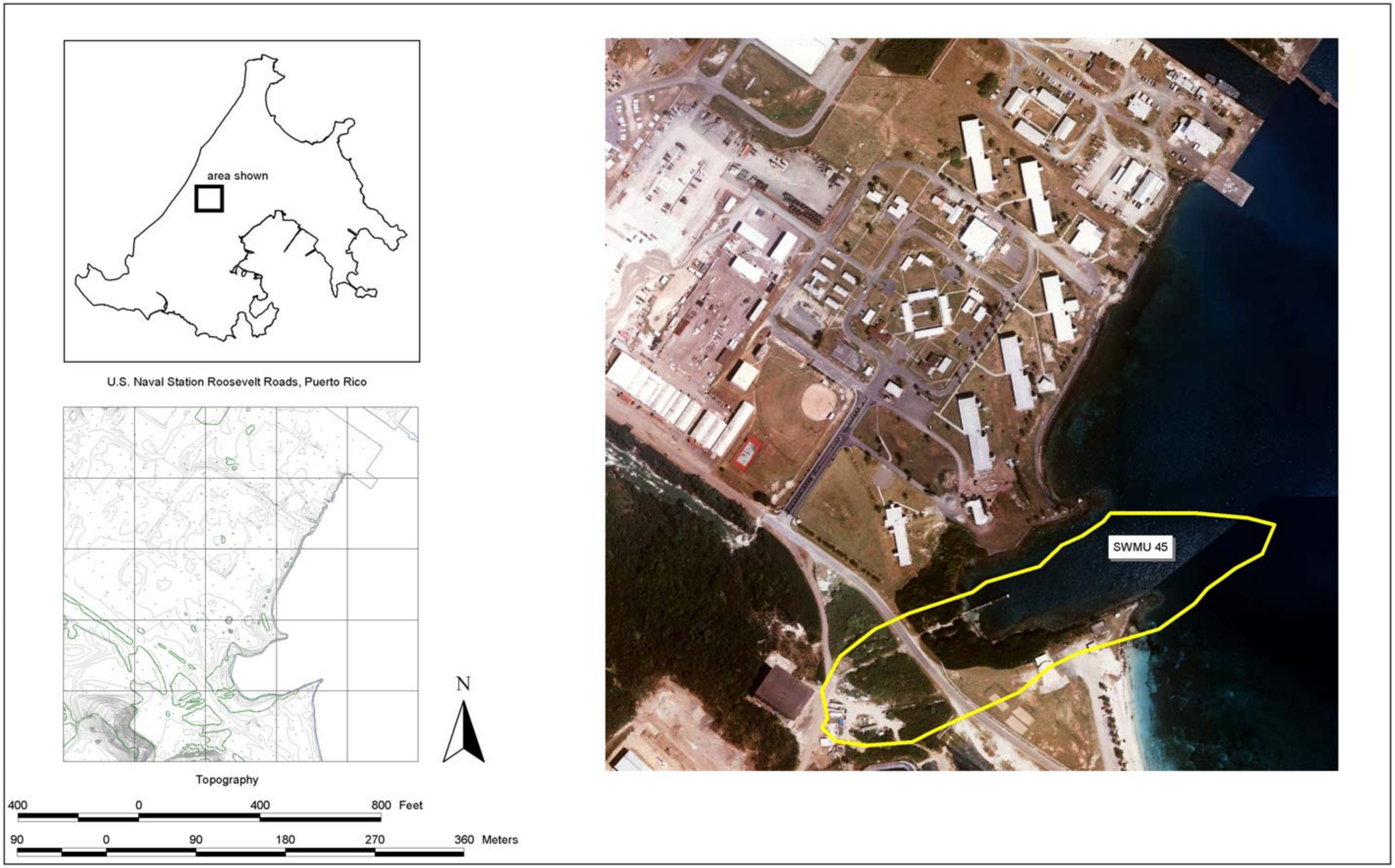

Figure 11. Location of SWMU 45, Roosevelt Roads, Puerto Rico

Figure 12. SWMU 45, Along the Shoreline of the Cove, Killdeer (*Charadrius vociferous*) Foraging Among Washed-up Seagrass.

Table 6

Vegetation Observed at SWMU 45

Common Name	Scientific Name	Stratum
Upland Coastal Forest		
bay flower	*Blutaparon vermiculare*	H
almácigo, turpentine-tree	*Bursera simaruba*	S/T
Barbados pride, dwarf poinciana	*Caesalpinia pulcherrima*	S
bottle wiss	*Capparis flexusa*	S
conchita de Virginia	*Centrosema virginianum*	V
none	*Chloris barbata*	H
péndula de sierra, fiddlewood	*Citharexylum caudafum*	S/T
copper	*Cordia alliodora*	S
none	*Dalbergia ecastaphyllum*	S
cotton	*Gossypium barbadense*	H
bay vine	*Ipomea pes-caprae*	V
willy vine	*Ipomea tiliacea*	V
tan tan, tanty, wild tamarind	*Leucaena leucocephala*	S
batatilla blanca	*Merremia quinquefolia*	V
Bellyache balsam, bitter bushplant	*Oncimum campechianum*	S
Prickly mampoo	*Pisonia aculeata*	S
guamá americano, guamuchil	*Pithcellobium dulce*	S
Christmas tree, tintillo	*Randia aculeata*	S
royal palm	*Roystonea borinquena*	S
bay flower, sea purslane, sea pusley	*Sesuvium portulacastrum*	H
None	*Sida rhombifolia*	S
Mangrove		
sea pusley	*Heliotropium curassavicum*	H
black mangrove	*Laguncularia racemosa*	S/T
None	*Stachytarpeta jamaicensis*	H/S
seaside mahoe, emajaguilla, portiatree	*Thespesia populnea*	S

S = shrub T = tree
H = herbaceous V = vine

Wildlife Description

During the short duration of wildlife surveys conducted on this site, numerous wildlife species such as birds and lizards were observed utilizing the habitat of this site (Table 7). Bird species were typical of coastal forest and shore species due to the proximity of the site to the open waters of Puerca Bay. There was no evidence that the SWMU site had an impact on the wildlife or habitat.

Protected Species

There were no federally protected species or preferred habitat observed at this site. The federally threatened plant *Stahlia monosperma* and the endangered Puerto Rican boa (*Epicrates inornatus*) would not be expected to inhabit the area since the site has been disturbed. Intact coastal forest habitat is not present (preferred habitat for the Puerto Rican boa) and only sparse black mangroves were present along the fringe of the Puerca Bay cove, so *Stahlia monosperma* would probably not occur. SWMU 45 is outside the area of critical habitat designation, although potential feeding habitat (shrubland) for the Yellow-shouldered blackbird was present at the site.

Table 7

Wildlife Observed at SWMU 45

English Name	Scientific Name	Local Name
Reptiles and Amphibians		
Lizard	*Anolis cristatellus*	Not known
Birds		
Killdeer	*Charadrius vociferous*	Playero Sabanero
Common-ground Dove	*Columbina passerina*	Rolita
Yellow Warbler	*Dendroica petechia*	Canario de Mangle
Magnificent Frigatebird	*Fregata magnificens*	Tijerilla (Rabijunco)
Pearly-eyed Thrasher	*Margarops fuscatus*	Zorzal Pardo
Northern Mockingbird	*Mimus polyglottos*	Ruiseñor
Cave Swallow	*Pterochelidon fulva*	Golondrina de Cuevas
Greater Antillean Grackle	*Quiscalus niger*	Mozambique (Chango)
Gray Kingbird	*Tyrannus dominicensis*	Pitirre
White-winged Dove	*Zenaida asiatica*	Tórtola Aliblanca
Zenaida Dove	*Zenaida aurita*	Tórtola Cardosantera

Food Web

A generalized food web for the upland coastal forest community is provided in Figure 6.

Marine Area

A reconnaissance survey of SWMU 45 was conducted June 19, 2000 (Dial Cordy and Associates Inc., 2000) to define the marine habitat and associated flora and fauna of the outfall structure and surrounding embayment and shore. Marine habitats observed in the study area included: rocky rubble subtidal zone, shallow subtidal sandy shelf, shelf slope, deep level bottom of embayment, and the outfall structure. A complete list of the marine flora and fauna observed at SWMU 45 is given in the Dial Cordy report (Dial Cordy and Associates Inc., 2000), which is included in Appendix B.

The rocky subtidal zone was located along the shoreline of the embayment and served as a means of shore protection. The rocky habitat was occupied by marine algal species (*Halimeda tuna*, *H. opuntia*, *Penicilllus pyriformis*, and *Udotea* species), invertebrates such as sea urchins (*Echinometra lucunter* and *E. viridis*), encrusting fire coral (*Millipora alcicornus*), common sea fan (*Gorgonia ventalina*), and starlet coral (*Siderastrea radians*). Sixteen fish species were seen and common species included sergeant major (*Abudefduf saxatillis*), dusky damselfish (*Stegastes fuscus*), tomtate (*Haemulon aurolineatum*), gray snapper (*Lutjanus griseus*), and squirrelfish (*Holocentrus* species). Most of the fish species were using the rocky zone for food and refuge from predators.

The shallow subtidal sandy shelf was characterized as a seagrass/algal bed dominated by turtle grass (*Thalassia testudinum*). Seagrass cover ranged from approximately 50 to 75 percent. Marine invertebrates included pincushion starfish (*Oreaster reticulatus*), several species of sea cucumbers, and the corkscrew anemone (*Bartholomea annulatta*). Common fish included the tomtate and gray snappers.

The shelf slope was devoid of seagrass and was characterized by marine algae. Fish observed included the yellowfin mojarra (*Gerres cinereus*) and silver jenny (*Eucinostomus gula*). The level sand bottom around the mouth of the outfall structure was un-vegetated and due to low visibility and depth, no large invertebrates or fish were observed.

The outfall structure itself supported a hardbottom community dominated by soft corals (*Leptogorgia* species, *Muricea elongata*, *Gorgonia ventalina*), marine algae (*Caulerpa racemosa* and *Cladophora* species), sponges (*Cliona* species), and fire coral.

CONCLUSION

The past activities at all to the SWMU sites presented in this report have some degree of impacts on their ecosystems. However, these impacts appear to be limited to changes in species composition based on physical disturbances. The construction of roads, rounds maintenance, and the addition of an outfall structure to the cove at Puerca Bay were only disturbances that have caused noticeable differences. Wildlife at these sites seems to be healthy and utilizing the habitats to their fullest extent. Through these surveys, no federally protected species were identified at these sites.

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APPENDIX A

Birds Potentially Occurring at NAVSTA Roosevelt Roads

Pied-billed grebe (*Podilymbus podiceps*)
Red-billed tropicbird (*Phaethon aethereus*)
Brown pelican (*Pelecanus occidentalis*)
Brown booby (*Sula leucogaster*)
Magnificent frigatebird (*Fregata magnificens*)
Great blue heron (*Ardea herodias*)
Louisiana heron (*Hydranassa tricolor*)
Snowy egret (*Egretta thula*)
Great egret (*Egretta alba*)
Striated heron (*Butorides striatus*)
Little blue heron (*Florida caerulea*)
Cattle egret (*Bubulcus ibis*)
Least bittern (*Ixobrychus exilis*)
Yellow-crowned night heron (*Nyctanassa violacea*)
Black-crowned night heron (*Nycticorax nycticorax*)
White-cheeked pintail (*Anas bahamensis*)
Blue-winged teal (*Anas discors*)
American widgeon (*Anas americana*)
Red-tailed hawk (*Buteo jamaicensis*)
Osprey (*Pandion haliaetus*)
Merlin (*Falcon columbarius*)
Clapper rail (*Rallus longirostris*)
American coot (*Fulica americana*)
Caribbean coot (*Fulica caribaea*)
Common gallinule (*Gallinula chloropus*)
Piping plover (Charadrius melodus)
Semipalmated plover (*Charadrius semipalmatus*)
Black-bellied plover (*Squatarola squatarola*)
Wilson's plover (*Charadrius wilsonia*)
Killdeer (*Charadrius vocifera*)
Ruddy turnstone (*Arenaria interpres*)
Black-necked stilt (*Himantopus himantopus*)
Whimbrel (*Numenius phaeopus*)
Spotted sandpiper (*Actitis macularia*)
Semipalmated sandpiper (*Calidris pusilla*)
Short-billed dowitcher (*Limnodromus griseus*)
Greater yellowlegs (*Tringa melanoleauca*)
Lesser yellowlegs (*Tringa flavipes*)
Willet (*Catoptrophorus semipalmatus*)
Stilt sandpiper (*Micropalama himantopus*)
Pectoral sandpiper (*Calidris melanotos*)
Laughing gull (*Larus atricilla*)
Royal tern (*Thalasseus maximus*)
Sandwich tern (*Thalasseus sandvicensis*)
Bridled tern (*Sterna anaethetus*)
Least tern (*Sterna albifrons*)
Brown noddy (*Anous stolidus*)
White-winged dove (*Zenaida asiatica*)
Zenaida dove (*Zenaida aurita*)
White-crowned pigeon (*Columba leucocephala*)
Mourning dove (*Zenaida macroura*)
Red-necked pigeon (*Columba squamosa*)
Common ground dove (*Columba passerina*)
Bridled quail dove (*Geotrygon mystacea*)

Birds Potentially Occurring at NAVSTA Roosevelt Roads (Continued)

Ruddy quail dove (*Geotrygon montana*)
Caribbean parakeet (*Aratinga pertinax*)
Smooth-billed ani (*Crotophaga ani*)
Yellow-billed cuckoo (*Coccyzus americanus*)
Mangrove cuckoo (*Coccyzus minor*)
Short-eared owl (*Asio flammeus*)
Chuck-will's-widow (*Caprimulgus carolinensis*)
Common nighthawk (*Chordeiles minor*)
Antillean crested hummingbird (*Orthorynchus cristatus*)
Green-throated carib (*Sericotes holosericeus*)
Antillean mango (*Anthracothorax dominicus*)
Belted kingfisher (*Ceryle alcyon*)
Gray kingbird (*Tyrannus dominicensis*)
Loggerhead kingbird (*Tyrannus caudifasciatus*)
Stolid flycatcher (*Myiarchus stolidus*)
Caribbean elaenia (*Elaenia martinica*)
Purple martin (*Progne subis*)
Cave swallow (*Petrochelidon fulva*)
Barn swallow (*Hirundo rustica*)
Northern mockingbird (*Mimus polyglottos*)
Pearly-eyed thrasher (*Maragarops fuscatus*)
Red-legged thrush (*Mimocichla plumbea*)
Black-whiskered vireo (*Vireo altiloquus*)
American redstart (*Setaophaga ruticilla*)
Parula warbler (*Parula americana*)
Prairie warbler (*Dendroica discolor*)
Yellow warbler (*Dendroica petechia*)
Magnolia warbler (*Dendroica magnolia*)
Cape May warbler (*Dendroica tigrina*)
Black-throated blue warbler (*Dendroica caerulescens*)
Adelaide's warbler (*Dendroica adelaidae*)
Palm warbler (*Dendroica palmarum*)
Black and white warbler (*Mniotilta varia*)
Ovenbird (*Seiurus aurocapillus*)
Northern water thrush (*Seiurus noveboracensis*)
Bananaquit (*Coerba flaveola*)
Striped-headed tanager (*Spindalis zena*)
Shiny cowbird (*Molothrus bonariensis*)
Black-cowled oriole (*Icterus dominicensis*)
Greater Antillean grackle (*Quiscalis niger*)
Yellow-shouldered blackbird (*Agelaius xanthomus*)
Hooded mannikin (*Lonchura cucullata*)
Yellow-faced grassquit (*Tiaris olivacea*)
Black-faced grassquit (*Tiaris bicolor*)
Least sandpiper (*Calidris minutilla*)
Western sandpiper (*Calidris mauri*)
Puerto Rican woodpecker (*Melanerpes portoricensis*)
Rock dove (*Columba livia*)
Puerto Rican emerald (*Chlorostilbon maugeus*)
Puerto Rican flycatcher (*Myiarchus antillarum*)
Pin-tailed whydah (*Vidua macroura*)
Spice finch (*Lonchura punctulata*)
Ruddy duck (*Oxyura jamaicensis*)
Peregrine falcon (*Falco peregrinus*)

Birds Potentially Occurring at NAVSTA Roosevelt Roads (Continued)

Marbled godwit (*Limosa fedoa*)
Puerto Rican lizard cuckoo (*Saurothera vieilloti*)
Prothonotary warbler (*Protonotaria citrea*)
Green-winged teal (*Anas carolinensis*)
Orange-cheeked waxbill (*Estrilda melpoda*)
Least grebe (*Tachybaptus dominicus*)
West Indian whistling duck (*Dendrocygna arborea*)
Puerto Rican screech owl (*Otus nudipes*)
Puerto Rican tody (*Todus mexicanus*)

Source: U.S. Navy 1998b.

APPENDIX B

Marine Resource Survey of SWMU Site
NAS Roosevelt Roads, Puerto Rico

July 18, 2000

Prepared for:
Geo-Marine, Inc.
Centro Punta Del Este, Suite 201
Fajardo, Puerto Rico 00738

Prepared by:
Dial Cordy and Associates Inc.
115 Professional Drive, Suite 104
Ponte Vedra Beach, FL 32082

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1.0 INTRODUCTION

Dial Cordy and Associates Inc. conducted a reconnaissance survey of the SWMU 45 Site at NAS Roosevelt Roads on June 19, 2000. The marine biological survey was conducted for Geo-Marine, Inc. in support of their Ecological Risk Assessment for the installation. Objectives of the brief survey included defining the marine habitats and associated flora and fauna and identifying species observed which may be indicators of present conditions. Representative still photographs and video documentation of the site were also completed.

2.0 HABITAT DESCRIPTION

Marine habitats observed in the study area included a rocky-rubble subtidal zone located around most of the embayment, a shallow subtidal sandy shelf located seaward of the rocky shore, a shelf slope extending to the base of the slope, a deeper level bottom, and the outfall structure. A brief description of the biological communities observed within these habitat types is provided below.

2.1 Rocky Subtidal Zone

Rock rip-rap is located along the shoreline on both sides of the embayment, principally to serve as means of shore protection. The riprap extends from above MHW to approximately 3 feet below MLW. This rock habitat is occupied by a myriad of marine algal species attached to the rocks, as well as numerous sessile and motile epibiota and marine fish (Table 1, Photographs 1-4). Dominant algal species include *Halimeda tuna*, *H. opuntia*, *Penicillus pyriformis,* and *Udotea sp*. Common marine invertebrates observed included sea urchins (*Echinometra lucunter* and *E. viridis*), encrusting fire coral *(Millipora alcicornus*), common sea fan (*Gorgonia ventalina*), and starlet coral (*Siderastrea radians*). Sixteen species of marine fish were observed within the rocky zone. Many of these are species are more common to seagrass beds, but move to this zone for food and refugia from predators. Common species observed include sergeant major (*Abudefduf saxatillis*), dusky damselfish (Stegastes fuscus), tomtate (*Haemulon aurolineatum*), gray snapper *(Lutjanus griseus),* and squirrelfish (*Holocentrus sp*.). As shown in Table 1, 11 species of fish are classified as rarely observed. Of the 16 species observed, five were juveniles, which often reside in shallow interior seagrass beds or reefs during their earlier life stages, prior to moving to offshore reef environments upon reaching maturity.

Table 1   Marine Flora and Fauna Observed at SWMU Site on June 19, 2000

			Rocky Subtidal	Sandy Shelf	Shelf Slope	Outfall Structure
MARINE FLOWERING PLANTS						
	Thalassia testudinum		x	x	x	
	Syringodium filiforme			x		
ALGAE						
Green Algae						
	Acetabularia calyculus		x			
	Penicillus pyriformis		x			
	Cladophora sp.		x			x
	Caulerpa sertularioides		x			
	Caulerpa racemosa		x			x
	Dictyosphaeria ocellata		x			
	Udotea sp.		x	x	x	
	Avrainvillea nigricans		x			
	Halimeda tuna		x			
	Halimeda opuntia		x	x	x	
	Penicillus capitatus			x		
	Halimeda incrassata			x	x	
Brown Algae						
	Dictyota cervicornis		x			
	Dictyopteris sp.		x			
	Padina sp.		x	x	x	
Red Algae						
	Wrangelia argus		x			x
	Laurencia papillosa		x	x		
INVERTEBRATES						
c	*Cliona sp.*	red boring sponge	x			x
r	*Holopsamma sp.*	lumpy overgrowing sponge	x	x		
r	*Bartholomea annulata*	corkscrew anemone	x	x		
r	*Condylactis gigantea*	giant anemone	x			
c	*Millepora alcicornis*	branching fire coral	x			x
r	*Muricea elongata*	orange spiney sea rod				x
c	*Gorgonia ventalina*	common sea fan	x			x
c	*Leptogorgia sp.*	sea whip				x
c	*Siderastrea radians*	lesser starlet coral	x			x
c	*Sabellastarte magnifica*	feather duster	x			
r	*Cyphoma macgintyi*	spotted cyphoma	x			
r	*Oreaster reticulatus*	cushon sea star		x	x	
ab	*Echinometra lucunter*	rock boring urchin	x			
ab	*Echinometra viridis*	reef urchin	x			
r	*Actinopyga agassizii*	five-toothed sea cucumber		x	x	
c	*Holothuria mexicana*	donkey dung sea cucumber		x		
FISH						
r	*Chaetodon ocellatus*	spotfin butterflyfish	x			

			Rocky Subtidal	Sandy Shelf	Shelf Slope	Outfall Structure
r	*Pomacantus paru*	French angelfish (juv)	x			
r	*Acanthurus coeruleus*	blue tang (juv)	x			
r	*Sphyraena barracuda*	great baracuda		x		
c	*Gerres cinereus*	yellowfin mojarra (juv)		x	x	
r	*Archosargus rhomboidalis*	sea bream				x
c	*Calamus penna*	sheepshead porgy (adult)		x		
c	*Eucinostomus gula*	silver jenny (juv)		x	x	
c	*Haemulon aurolineatum*	tomtate (juv)	x	x		
c	*Lutjanus griseus*	gray snapper (juv)	x			x
r	*Lutjanus aoidus*	schoolmaster snapper	x	x		
c	*Stegastes fuscus*	dusky damselfish (adult)	x			x
r	*Stegastes leucostictus*	Beaugregory	x			
ab	*Abudefduf saxatillis*	sergeant major	x			x
r	*Serranus tigrinus*	harlequin bass	x			
r	*Sparisoma aurofrenatum*	redband parrotfish (juv)	x	x		
r	*Halichoeres bivittatus*	slippery dick	x	x		
c	*Holocentrus sp.*	squirrelfish	x			
r	*Coryphopterus glaucofraenum*	bridled goby	x			
r	*Aulostomus maculatus*	trumpetfish	x			
r	*Sphoeroides spengleri*	bandtail puffer	x			

r = rare
ab = abundant
c = commom

2.2 Shallow Subtidal Shelf

This zone occurs between the rocky subtidal zone and the deeper shelf slope, from 3-10 feet below MSL. The shelf is characterized as a seagrass/ algal bed dominated by turtle grass (*Thalassia testudinum*) and marine algae including *Halimeda incrassata, H. opuntia, Udotea sp., Padina sp*., and *Penicillus capitatus*. (Photographs 5 & 8). Seagrass cover values based on the Braun Blanquet Method (Braun-Blanquet, 1965) ranged from 50% to greater than 75% for the turtle grass beds. Marine invertebrates observed included the pin cushion star fish (*Oreaster reticulatus*), sea cucumbers (*Actinopyga agassizii, Holothuria mexicana*), and the corkscrew anemone (*Bartholomea annulatta*) (Table 1). Fish common to the seagrass habitat included tomtate (*Haemulon aurolineatum*, gray snapper (*Lutjanus griseus*), and several species of mojarras.

The shelf area at the back end of the basin is a sandy bottom habitat with little to no seagrass or algae present. The bottom is covered with active mounds created by callianassid burrowing shrimp. Mojarras were the only family of fish observed in this area. An abundance of drift algae was observed covering the bottom.

2.3 Shelf Slope

The shelf slope ranged from 10-15 feet below MSL around the perimeter of the basin. This area was void of seagrass and characterized by marine algae including *Padina* s*p, Udotea* sp*., and Halimeda spp* (Photographs 7 & 8). No conspicuous motile epibenthic species were observed in this habitat. Fish observed included yellowfin mojarrra (*Gerres cinereus*) and silver jenny (*Eucinostomus gula*).

2.4 Level Sandy Bottom

The interior of the basin from the mouth to and around the outfall structure is unvegetated sand to silty-sand bottom. Due to low visibility and depth (15-20 feet), no large invertebrates or fish were observed.

2.5 Outfall Structure

The concrete side walls of the outfall structure support a hardbottom community dominated by soft corals (*Leptogorgia* sp., *Muricea elongata*, *Gorgonia ventalina*,), marine algae (*Caulerpa racemosa*, *Cladophora* sp.), sponges (*Cliona* sp.), and fire coral (*Millipora alcicornus*). A list of species observed is provided in Table 1. Representative species are illustrated in Photographs 9 and 10.

3.0 INDICATOR SPECIES

Species which may serve as indicators of the present environmental quality of the site are listed below. The absence of seagrass and selected invertebrate species in the future would serve to indicate a change in the quality of the habitat and associated water quality in the embayment. Fish species selected are mobile and their absence may not reflect a significant change. The absence of many of the common species observed in association with the rocky shoreline would indicate a significant change had occurred.

Indicator Species	
Thalassia testudinum	turtle grass
Condylactis gigantea	giant anemone
Echinometra viridis	reef urchin
Siderastrea radians	lesser starlet coral
Chaetodon ocellatus	spotfin butterflyfish
Stegastes fuscus	dusky damselfish

4.0 REFERENCES

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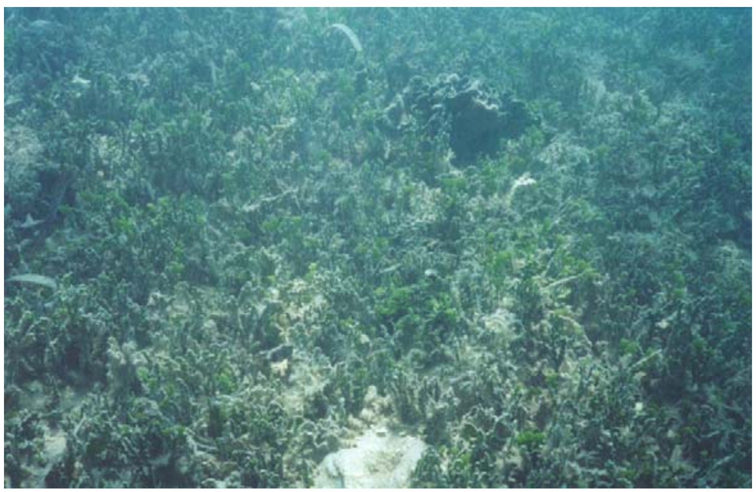
APPENDIX A

Photographs

Photogragh 1. Rocky subtidal habitat with squirrelfish (*Holocentrus adcensionis*).

Photogragh 2. Rocky subtidal habitat and seagrass bed interface with calcareous green algae (*Halimeda incrassata)*, turtle grass (Thalassia testudinum) and porous sea rods (*Pseudoplexaura sp*.).

Photograph 5. Seagrass habitat on shallow shelf dominated by turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).



Photograph 7. Shelf slope habitat characterized by green algae (*Halimeda incrassata* and *H. opuntia*).

Photograph 6. Seagrass habitat with turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*) and green algae *(Halimeda incrassata*).

Photograph 8. Shelf slope habitat characterized by green algae (H*alimeda incrassata* and *H. opuntia*) and scattered turtle grass (*Thalassia testudinum*).

Photograph 9. Hard substrate community on outfall structure with red boring sponge (Cliona sp.) and feather duster worm.

Photograph 10. Gorgonian soft corals located on outfall structure.